Role of Imaging in Rhinology

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Otolaryngologist's

Perspective

More than 250 Images

About the author

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Introduction

X-rays in the present day context is considered to be outdated by Rhinologists. CT scan images have replaced conventional x-ray imaging. Current consensus is that still x-rays have a role in the field of rhinology. Its inherent advantages like easy availability, cost effectiveness makes this investigation still relevant in the present day scenario. Bony lesions involving nose and sinuses, can be evaluated with reasonable degree of accuracy by performing conventional radiographs. Air present inside the paranasal sinuses serve as excellent contrast medium for plain x-ray evaluation. Pathologies involving paranasal sinuses encroach upon these air spaces causing alterations in their translucency

With the advent of CT / MRI imaging plain radiographs are losing their relevance as far as rhinological diagnosis is concerned. This article attempts to explore the currently prevailing indications for the use of plain radiographs in rhinology. Even though CT scan provides improved resolution of soft tissue densities it has its own draw backs like increased cost of investigation and not so easy availability. Paranasal sinuses are air filled cavities. Pathology involving these structures cause varying degrees of attenuation of these air contrast medium which can easily be observed in any conventional radiographs. Certain pathological conditions can cause accumulation of fluid within the sinus cavity. This can be clearly demonstrated if plain x-rays are taken with patient in erect position. Fluid levels can clearly be demonstrated even in plain radiographs.

X-ray Imaging

Advantages of x-ray imaging in rhinology include:

1. Cost effectiveness of the investigation

2. Easy availability

3. Currently available digital x-ray imaging techniques provide better soft tissue and bone resolution when compared to conventional x-rays.

Disadvantages of conventional radiographs:

1. Plain radiographs have a false positive rate of 4% [1].

2. Plain radiographs have false negative rate of more than 30% [2].

3. Difficulties in patient positioning

If the antrum in water's view demonstrates a loss of translucency which could be an indicator of fluid level, then another x ray is taken with a tilt of saggital plane to an angle of 30 degrees. This view will clearly demonstrate movement of fluid to a new position. In this view the fluid moves towards the lateral portion of the antrum where it can clearly be seen.
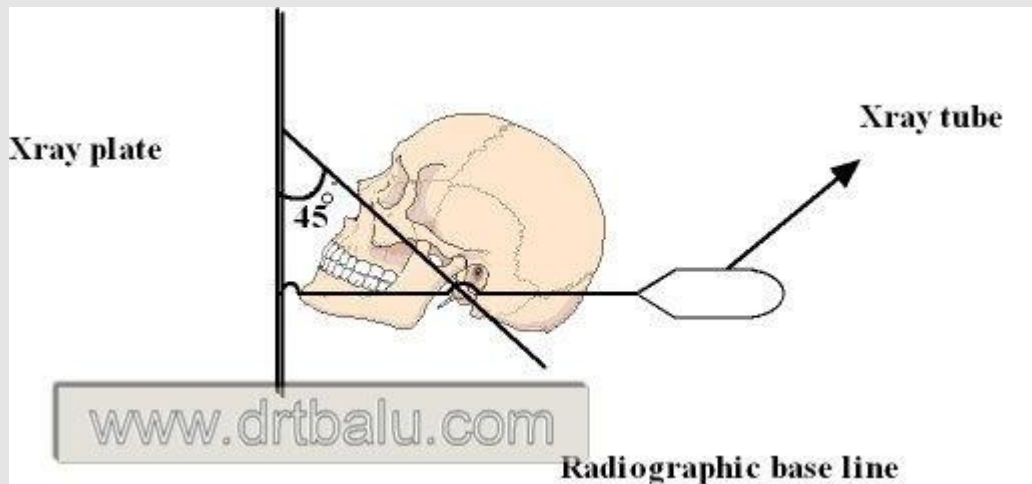
Image showing patient positioning in x-ray sinus Water's view

In x-ray pararanasal sinuses water's view chronic maxillary sinusitis is displayed as:

1. Clouding of maxillary sinuses

2. Opacification of maxillary sinuses

3. Mucosal thickening of maxillary sinuses

4. Fluid level seen in the maxillary sinuses

Among these 4 signs least accurate happens to be clouding of maxillary sinuses. This has a false positive value of more than 30% in some studies. Total opacification of maxillary sinus is a more reliable sign of infection with accuracy levels ranging between 80-92% [4].

Sources for error in interpreting xray paranasal sinuses waters view could be:

1. Anatomical

2. Technical

Anatomical causes for interpretation errors in x-ray +paranasal sinuses water's view:

1. Hypoplastic sinus – This could cause clouding / total opacification of maxillary sinus

2. Orbital floor exposure- This could appear as false mucosal thickening

3. Zygomatic recess – This could appear as false mucosal thickening

4. Superior orbital fissure- This could appear as false mucosal thickening or false interpretation as fluid level.

Technical causes for interpretation errors in x-ray paranasal sinuses water's view include:

1. Soft exposure – This can cause an impression of clouding of maxillary sinuses

2. Lateralization of radiographic tube – This will cause mucosal thickening on the side of lateralization to be missed in the radiograph.

3. Inadequate tilting of tube / head – This will cause an artificial impression of presence of fluid level.

4. Marked tilting of tube / head – This will cause impression of clouding of maxillary sinuses

5. Patient in recumbent position – This can cause retained secretions in the maxillary sinuses to be missed.

X-ray paranasal sinuses Water's view clearly shows:

1. Maxillary sinuses

2. Frontal sinus

3. Ethmoidal sinuses

4. Orbit

5. Sphenoid sinus

6. Nasal cavities

7. Alveolar arches

9. Zygoma

Standard radiograph positions for studying nose and paranasal sinuses:

Radiographic study of paranasal sinuses are standardized around three positions. These include:

1. Two anatomical positions – Coronal and saggital

2. Radiographic – This position pertains to radiographic baseline. This is actually an imaginary line drawn from the outer canthus of the eye to the mid point of external auditory canal.

Positions used to study paranasal sinuses include:

1. Occipito mental view (water's view)

2. Occipital frontal view (Caldwell view)

3. Submento-vertical view (Hirtz view)

Water's view:

Also known as occipito mental view is the commonest view taken. This view was developed by Waters and Waldron in 1915. This was actually a modification of occipito frontal projection (Caldwell view) 3. Patient is made to sit facing the radiographic base line tilted to an angle of 45 degrees to the horizontal making the sagittal plane vertical. The radiological beam is horizontal and is centred over a point 1 inch above the external occipital protuberance. In obese patients with a short neck it is virtually impossible to obtain an angulation of 45 degrees. These patients must be made to extend the neck as much as possible and the x-ray tube is tilted to compensate for the difference in angulation. The mouth is kept open and the sphenoid sinus will be visible through the open mouth. If the radiograph is obtained in a correct position the skull shows a foreshortened view of the maxillary sinuses, with the petrous apex bone lying just beneath the floor of the maxillary antrum. In this view the maxillary sinuses, frontal sinuses and anterior ethmoidal sinuses are seen. The sphenoid sinus can be seen through the open mouth.

X-ray paranasal sinuses water's view is still a viable investigation in patients with facio maxillary trauma. Examination of Dolan's line in x-ray sinuses water's view helps in identifying patients with zygomatico-maxillary complex fractures.
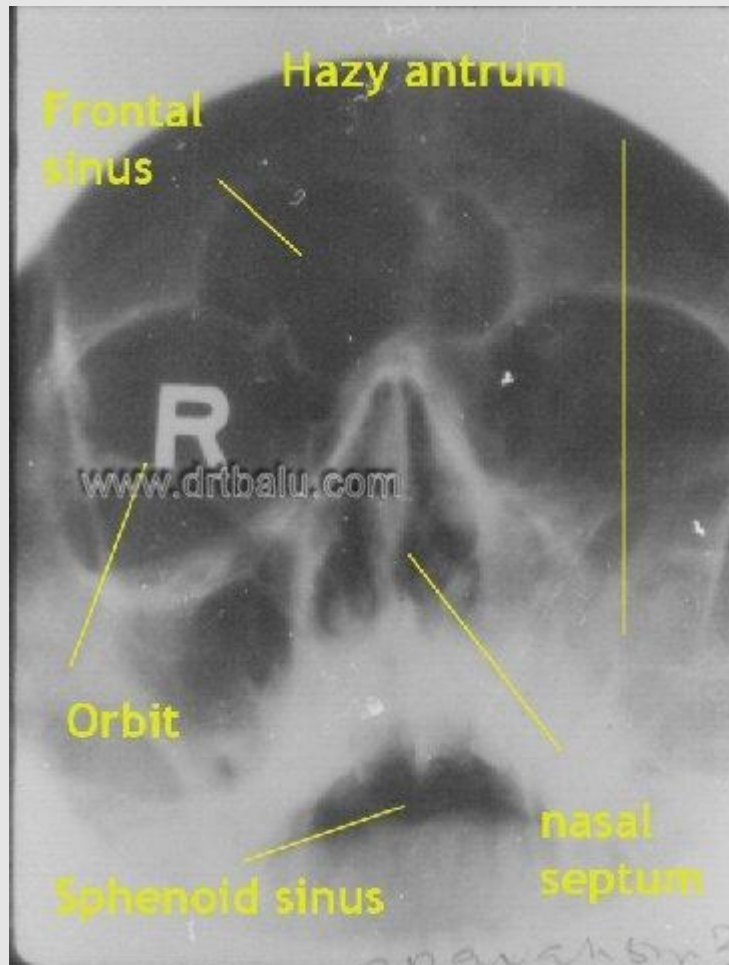
X-ray sinus Water's view

Dolan's line:

This was first popularized by Dolan etal. They described three lines which in conjunction resembled elephant's head in profile.

1. Orbital line – This resembles the elephant's ear. Disruption of this line could be due to fracture through lateral orbital rim or diastasis of fronto-zygomatic suture line. Disruption of inferior portion of orbital line could be due to fracture involving inferior rim of orbit / floor of orbit.

2. Zygomatic line – This line resembles elephant's forehead and trunk. This line follows the lateral orbital rim to the superior margin of zygomatic arch. Disruption of this line indicates fracture involving zygoma.

3. Maxillary line – This resembles elephant's chin and trunk. This line follows the lateral wall of the maxillary sinus to the inferior margin of zygomatic arch. Fractures are expected in this zone.

Figure showing Dolan's line

In x ray para nasal sinuses waters view the normal frontal sinus margins show scalloping. Loss of this scalloping is a classic feature of frontal mucocele. If frontal sinus is congenitally absent (agenesis) then a suture line known as the metopic suture is visible in the fore head area. Sometimes a pair of large anterior ethmoidal air cells may take up the place of frontal sinuses. Here too the metopic suture line is visible. This suture divides the two halves of frontal bone of the skull in infants and children.

This suture line usually disappears at the age of 6 when it fuses. If this suture is not present at birth it will cause a keel shaped deformity of the skull (trigonocephaly).
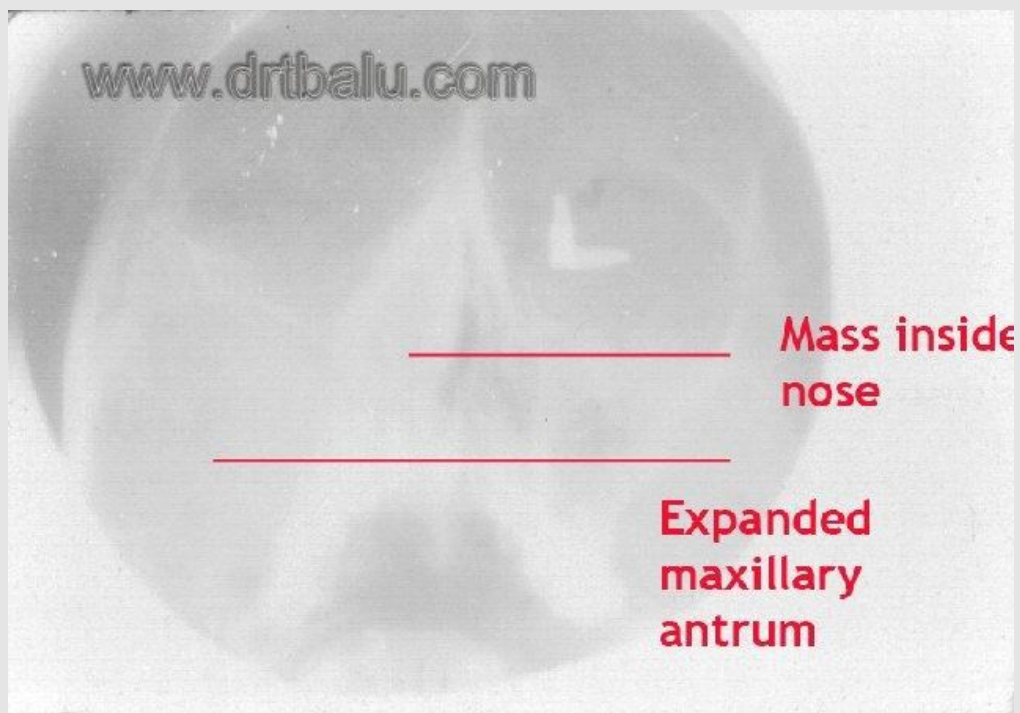

X-ray sinuses water's view showing Metopic suture with Hypoplastic maxillary sinus and absent frontal sinus

Expansion is characterised by increase in the size of maxillary antrum when compared to its counter part on the opposite side.

Erosion may occur in the medial wall of the antrum or in its antero lateral wall. The canine fossa area is the thinnest portion of maxillary antrum antero lateral wall. Erosion is hence common in this area.

Opacity is the term used to describe a maxillary sinus antra involved with malignant growth. This opacity is due to the periosteal reaction due to malignant growth.

X-ray sinuses water's view showing expansion and erosion of right maxillary antrum due to malignancy

According to Veterans Affairs general medicine clinic study 5 using the following criteria to diagnose sinusitis from x-ray sinuses water's view improved its accuracy to more than 80%. These criteria include:

1. Presence of air fluid level

2. Sinus opacity

3. Mucosal thickening greater than 6 mm
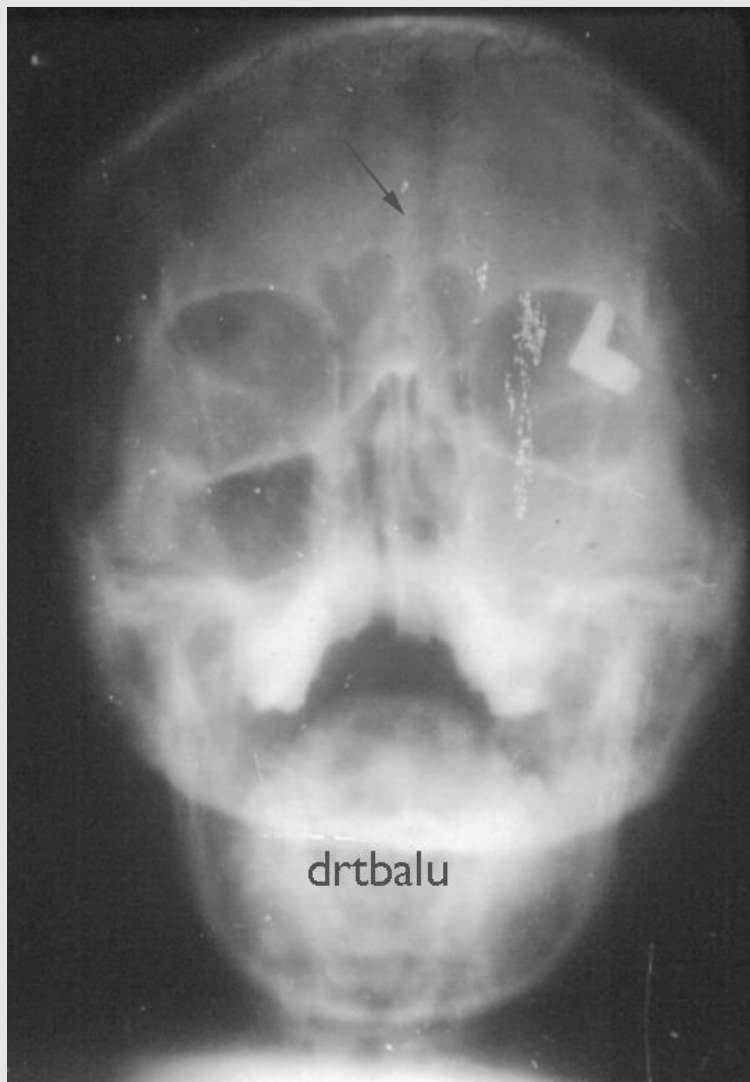
X-ray PNS water's view shows metopic suture (arrow) which is a persistent frontal suture.

Usually it disappears at the age of 6 with the normal development of frontal sinuses.

Persistence of Metopic suture (i.e. sutura frontalis persistens). In patients with agenesis of frontal sinuses the metopic suture is still persistent. In the above x-ray the frontal sinus is absent and is replaced by a pair of large anterior ethmoidal air cell. (* Note: The left maxillary sinus appear hazy, possibly due to sinusitis).

Routine CT scan imaging is not indicated routinely to diagnose patients with acute sinusitis. Even though it has high sensitivity in diagnosing acute sinusitis it has low specificity.   Studies reveal that more than 40% of asymptomatic patients too show CT scan abnormalities indicating presence of sinusitis 6.

Digital x-rays:

With the advent of digital imaging techniques the cost of imaging has drastically reduced. The quality of images generated are much better than analog ones which was captured on a film. In addition this procedure involves less amount of radiation to the patient when compared to that of conventional x-ray techniques.

Occipito-frontal view (Caldwell view):

This position is ideally suited for studying frontal sinuses. In this position the frontal sinuses are in direct contact with the film hence there is no chance for any distortion or geometric blur to occur. Hence it is ideally suited to create frontal sinus templates for external surgeries involving frontal sinuses.
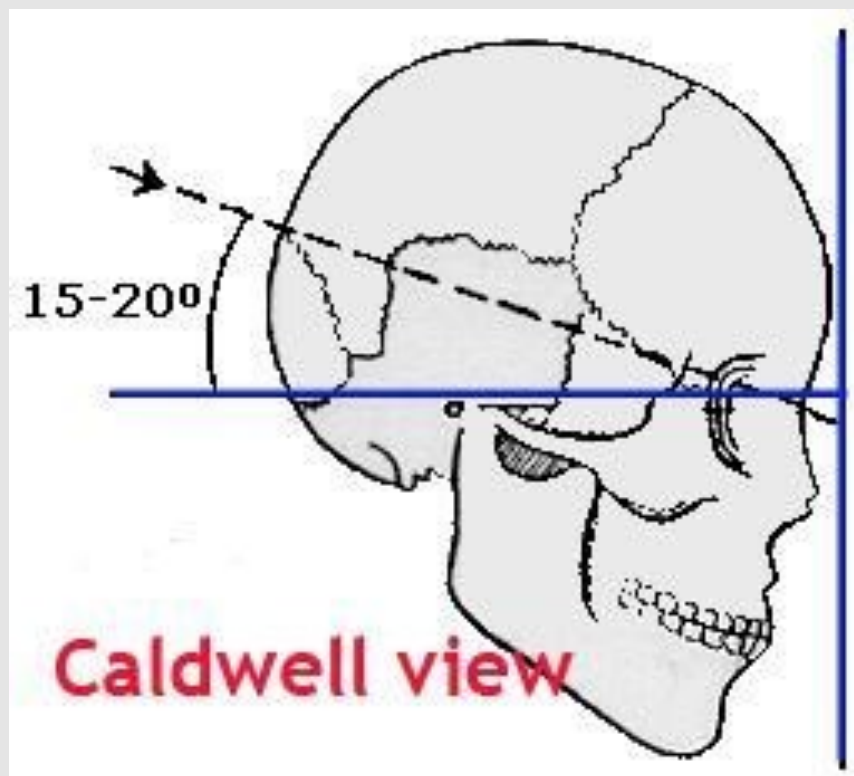
Figure showing patient position for Caldwell view radiograph

To get a Caldwell view the patient is made to sit in front of the film with the radiographic base line tilted to an angle of 15 – 20 degrees upwards. The incident beam is horizontal and is centred 1/2 inch below the external occipital protuberance. This view is also known as the frontal sinus view. In this view the petrous portion of the temporal bone obscures the visualization of maxillary sinuses. Frontal sinuses can be clearly studied using this view. This view also helps in templating the frontal sinus before external Fronto ethmoidectomy surgeries. This view also clearly demonstrates frontal and ethmoidal sinuses. Maxillary sinus is not clearly visible because the petrous apex obscures its view.

In this view a small indentation / groove can be seen along the upper portion of the medial wall of orbit. This groove is caused by anterior ethmoidal artery and nasociliary nerve. The ethmoido-maxillary plate is clearly seen in this view. This is actually a useful landmark for localizing spread of tumors.

X-ray sinuses caldwell view showing:

1- Frontal sinus

2- Ethmoid sinus

3-Petrous apex

4-Inferior orbital fissure

5-Maxillary sinus obscured by petrous apex

*- Site of anterior ethmoidal artery

Submentovertical view (Hritz view):

This view is primarily taken to view sphenoid sinus. Fluid levels in sphenoid sinuses are clearly shown in this view. To take an x ray in this position, the back of the patient is arched as far as possible so that the base of skull is parallel to the film. The x ray beam is centred in the midline at a point between the angles of the jaws. In elderly patients this view can be easier to achieve if carried out in the supine position with the head hanging back over the end of the table. This view also demonstrates the relative thicknesses of the bony walls of the antrum and the frontal sinuses.
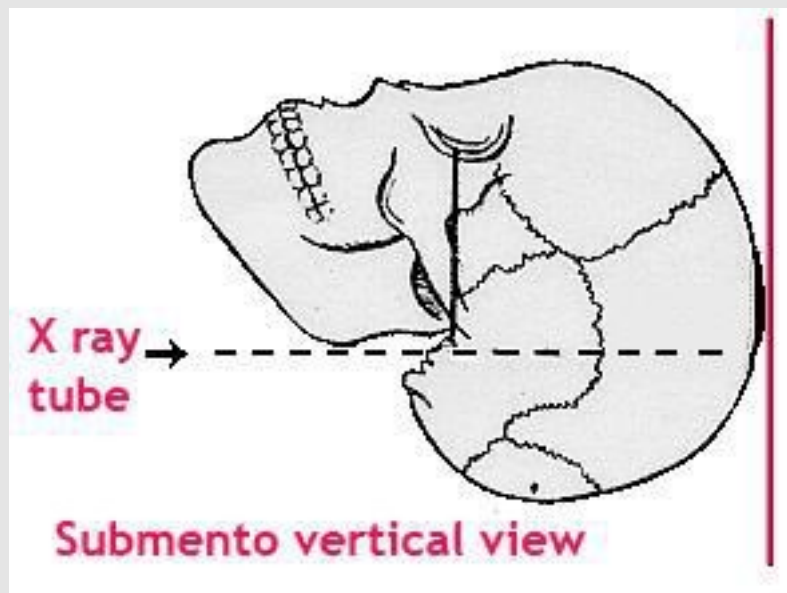

Figure showing positioning of patient for submento-vertical view

Fluid levels in sphenoid sinus can be clearly seen in this view. Zygomatic arch can also be clearly delineated in this view. This view is not popular these days because CT scans give better resolution of this area. CT scans have largely replaced this view.

Some pathological conditions that are clearly seen in sinus radiographs:
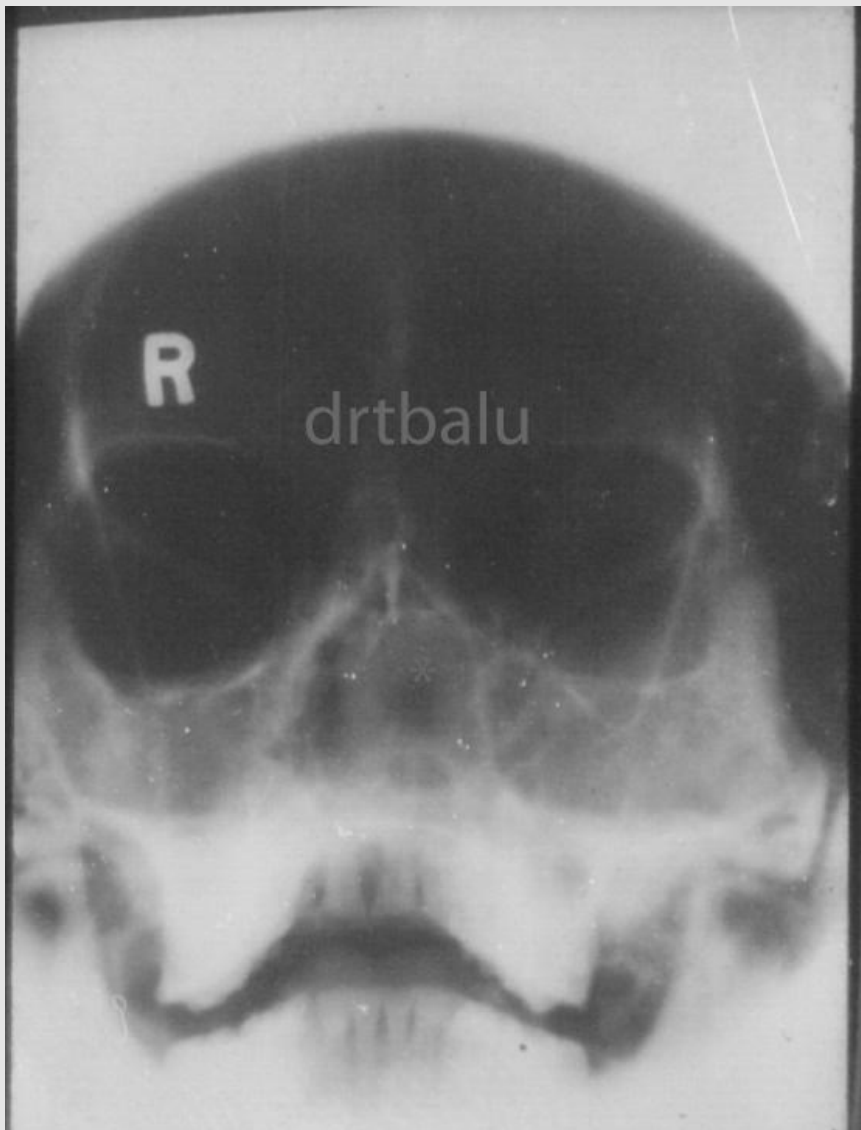
In the x-ray shown above, a swelling could be seen in the nasal septal area. Gas shadow could also be seen inside the swelling. This gas shadow could be caused by gas released by pyogenic organisms.

The cartilaginous portion of the nasal septum is not visible, could have been eroded. Probable diagnosis is septal abscess. Both the maxillary sinuses also appear hazy due to infection. Collection of pus between the Perichondrium and the nasal septal cartilage compromises the nutritional status of the cartilage as it is dependent on the Perichondrium for its nourishment. This cartilage undergoes necrosis. Septal abscess in this patient could have been caused by chronic sinus infection (i.e. Note haziness of both maxillary sinuses in this patient).
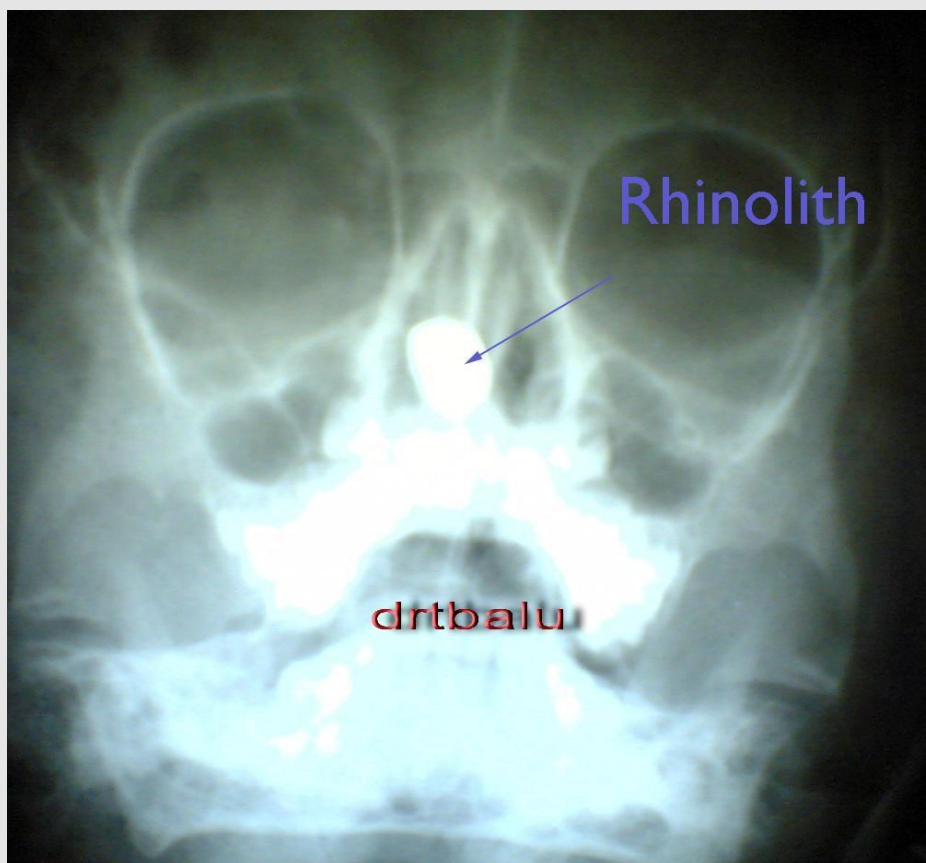

Image showing Rhinolith

X-ray lateral view:

This view helps in diagnosing pathologies involving frontal sinuses. It helps in determining whether the loss of translucency is due to thickening of the anterior bony wall or infection of the frontal sinus per se. This view also demonstrates fluid levels in the antrum. This view also gives information on the naso pharynx and soft palate. This is in fact a standard projection used to ascertain enlargement of adenoid tissue.
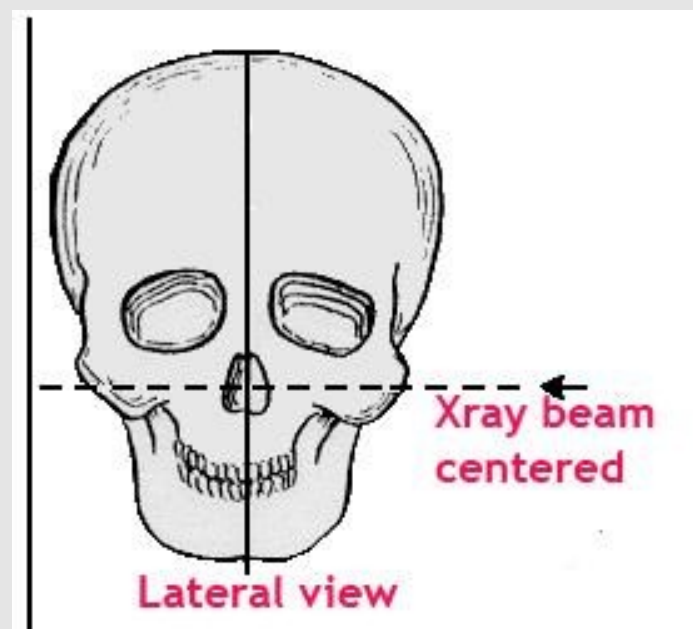

Figure showing skull position for x-ray skull lateral view

For this view the patient is made to sit with the sagittal plane parallel to the x-ray film and the radiographic base line is horizontal. The incident ray is horizontal and the incident beam is centred at the mid point of the antrum.

Oblique view:

This view helps in demonstrating posterior ethmoid air cells and optic foramen. To obtain this projection the patient is made to sit facing the film. The head is rotated so that the sagittal plane is turned to an angle of 39 degrees. The radiographic base line is at an angle of 30 degrees to the horizontal. The incident beam is horizontal and is centred so that the beam passes through the centre of the orbit nearest to the film.

X-ray nasal bone:

This is usually taken to rule out nasal bone fractures. One should be cautioned against misinterpreting groove for nasociliary nerve which could mimic fracture. Fracture nasal bones is actually a clinical diagnosis based on the following findings:

1. Tenderness over nasal bone area

2. Crepitus over nasal bone area

3. Swelling and deformity over nasal bone area

Image showing fractured nasal bone

Limitations of conventional X-rays:

1. Inefficient x-ray absorption causing 75% of useful data to go a waste

2. High scatter to Primary x-ray ratios—Creates background intensity un-related to overlying anatomy

3. Superimposition & Conspicucity—Conventional radiographs convert 3 dimensional images to 2 dimensional ones. This causes loss of useful data as well as causing data to become inconspicuous.

4. Receptor contrast versus latitude—Sufficient exposure latitude should be provided for anatomical structures to become visible in a plain ra-diograph. To make complex matters simple this is not possible in a conventional radiograph.

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History of CT Imaging

First CT scan was performed on 1st October 1971 at Atkinson Morley Hospital London. The patient was a lady suspected with Frontal Lobe tumour. Surgeon who performed the surgery remarked that the tumour resembled the scanned image accurately. The scanner used was the prototype devised by Godfrey Hounsfield and his team at EMI research lab. It was Ian Isherwood who presided over acquisition and evaluation of first commercial Brain CT scanner in the world at Manchester Royal Infirmary London. The first EMI Head Scanner had 2 detectors along the Z-axis.

First clinical CT scan was performed in US at Mayo Clinic. In 1973 [1.]

Godfrey Hounsfield

Sir Godfrey Hounsfield was awarded the Nobel Prize along with Cormack in 1979 for designing CT scanner [2]. 1980's was characterized by rapid advances in the field of CT imaging. In 1990 continuous scanning devices (Spiral CT scanners) were developed with just 0.5 sec scan times.

Basic principles of First CT scanner:

Hounsfield theorized the subject to be scanned being divided into axial slices. The x-ray beams used for scanning is collimated into pencil thin beams (3 mm). It is the beam width that specifies the scan thickness. The X-ray tube and the x-ray detector (situated on the opposite side) scans across the subject [3]. This scanning motion of the tube and the detector across the patient is known as a translation. During this motion measurements of x-ray transmission through the subject are made by detectors at many locations. The original CT scanner designed by Hounsfield was a brain scanner which was water cooled. The water filled box reduced the range of intensities over which the detector need to respond. The first waterless whole body scanner was developed by Ledlet etal in 1974 [4].

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Anatomy of Lateral Nasal wall

Introduction:

Anatomy of the lateral nasal wall is highly complex and variable. With the popularity of endoscopic sinus surgery a through knowledge of this complex anatomy is very vital. Highly variable anatomy and paucity of standard landmark makes this region vulnerable for complications during endoscopic sinus surgery. The learning curve for endoscopic sinus surgery is made rather steep by this highly variable anatomy [1]. Study of anatomy of lateral nasal wall dates back to Galen (AD 130-201). He described the porosity of bones in the head. Davinci in his classical anatomical drawings has illustrated maxillary sinus antrum. He also described maxillary sinus as cavities in the bone that supports the cheek [2]. Highmore (1651) described maxillary sinus anatomy. Hence it is also known as antrum of Highmore [3]. It was during the 19th century that Zuckerkandl came out with the first detailed description of maxillary sinus and its surrounding anatomy. Paranasal sinuses are four air filled cavities situated at the entrance of the upper airway. Each of these sinuses are named after the skull bone in which it is located [4].

Nasal turbinates:

The turbinates are the most prominent feature of the lateral nasal wall [5]. They are usually three or sometimes four in number. These turbinates appear as scrolls of bone, delicate, covered by ciliated columnar epithelium. These turbinates sometimes may contain an air cell, in which case it is termed as a concha.
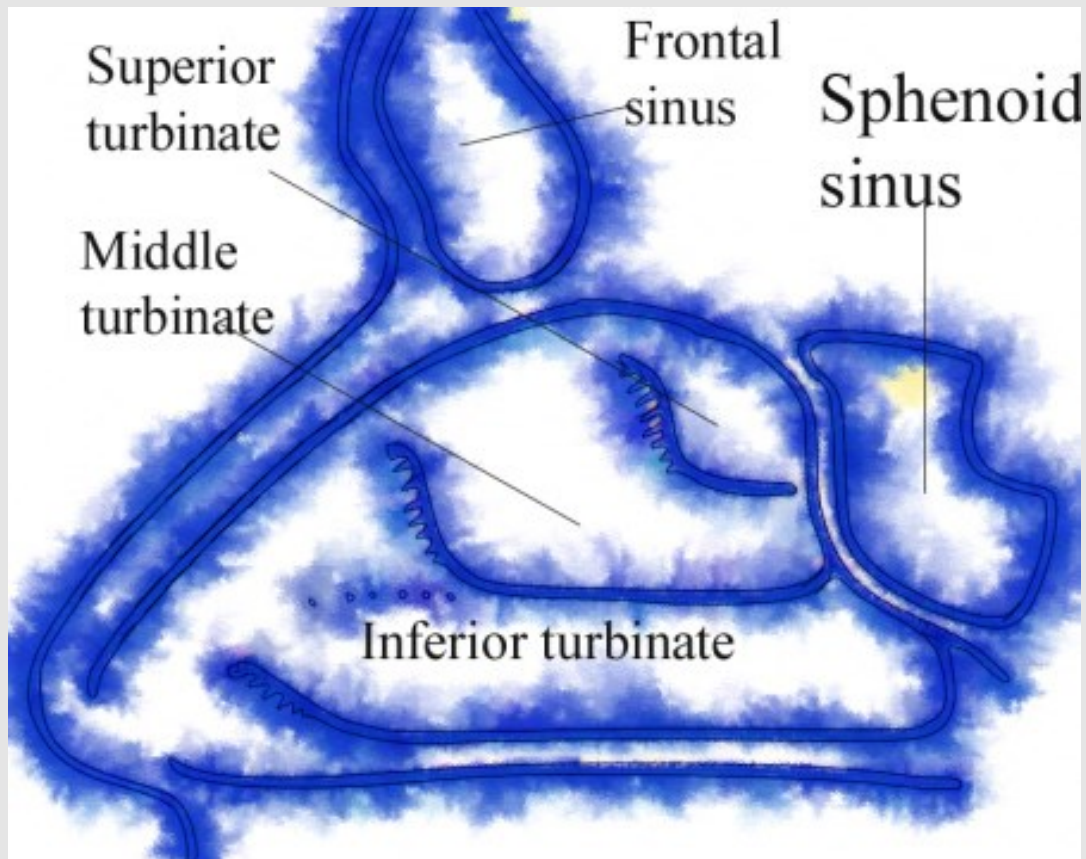
Figure showing t turbinates in the lateral nasal wall

These turbinates project from the lateral wall of the nose. Out of these turbinates the following are present in all individuals:

The superior, middle and inferior turbinates. A small supreme turbinate may be present in some individuals. Among these turbinates the superior and the middle turbinates are components of the ethmodial complex where as the inferior turbinate is a separate bone. Commonly a prominence may be seen at the attachment of the middle turbinate.
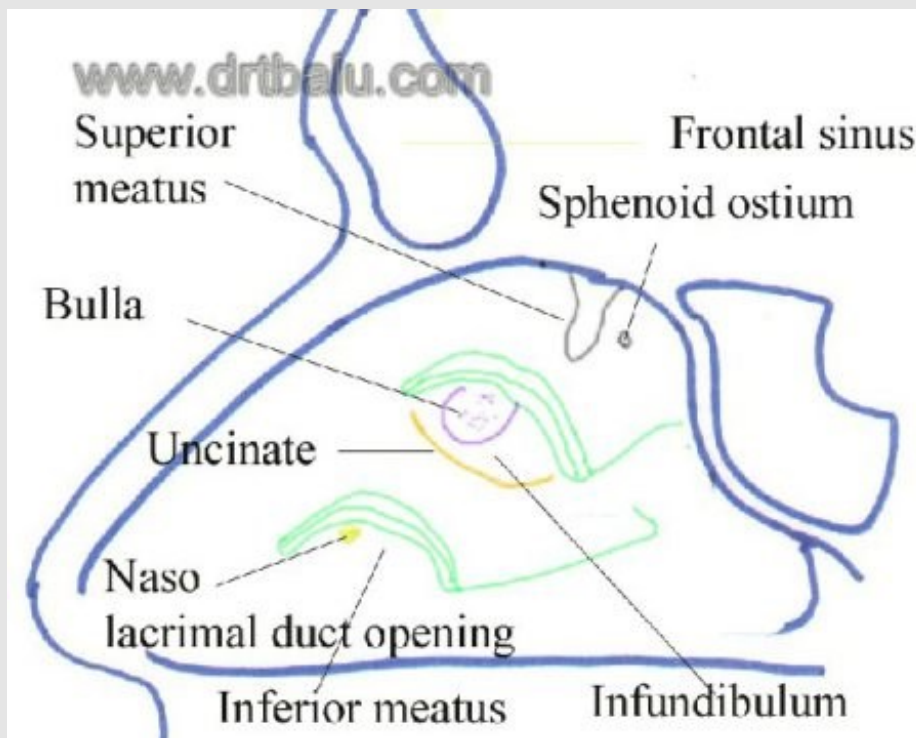
Image showing lateral nasal wall after removal of turbinates

This prominence is known as the agger nasi cell. This prominence varies in size in different individuals. These agger nasi cells overlie the lacrimal sac, separated from it just by a thin layer of bone. In fact this agger nasi cell is considered to be a remnant of naso turbinal bones seen in animals. When the anterior attachment of the inferior and middle turbinates are re-moved, the lacrimal drainage system and sinus drainage system can be clearly seen.

The inferior turbinate is a separate bone developed embryologically from the maxilloturbinal bone.

The inferior meatus is present between the inferior turbinate and the lat-eral nasal wall. The nasal opening of the naso lacrimal duct opens in the anterior third of the inferior meatus. This opening is covered by a mucosal valve known as the Hassner's valve. The course of the naso lacrimal duct from the lacrimal sac lie under the agger nasi cell.

The middle meatus lie between the middle turbinate and the lateral nasal wall. The middle turbinate is part of the ethmoidal complex. The sinuses have been divided into the anterior and posterior groups. The anterior group of sinuses are frontal, maxillary and anterior ethmoidal sinuses. These sinuses drain into the middle meatus, i.e. under the middle turbinate. The middle meatus hosts from anterior to posterior the following structures:

1. Agger nasi

2. Uncinate process

3. Hiatus semilunaris

4. Ethmoidal bulla

5. Sinus lateralis

6. Posterior fontanelle

Uncinate process: actually forms the first layer or lamella of the middle meatus. This is the most stable landmark in the lateral nasal wall. It is a wing or boomerang shaped piece of bone. It attaches anteriorly to the posterior edge of the lacrimal bone, and inferiorly to the superior edge of the inferior turbinate [6]. Superior attachment of the uncinate process is highly variable, may be attached to the lamina palyracea, or the roof of the ethmoid sinus, or sometimes to the middle turbinate. The configuration of the ethmoidal infundibulum and its relationship to the frontal recess depends largely on the behaviour of the uncinate process. The Uncinate process can be classified into 3 types depending on its superior attachment.

The anterior insertion of the uncinate process cannot be identified clearly because it is covered with mucosa which is continuous with that of the lateral nasal wall. Sometimes a small groove is visible over the area where the uncinate attaches itself to the lateral nasal wall.

 The anterior convex part forms the anterior boundary of the ostiomeatal complex. It is here the maxillary, anterior ethmoidal and frontal sinuses drain. Uncinate process can be displaced medially by the presence of polypoidal tissue, or laterally against the orbit in

individuals with maxillary sinus hypoplasia [7]. Removing of this piece of bone is the most important step in Endoscopic sinus surgery.

Type I uncinate: Here the uncinate process bends laterally in its upper most portion and inserts into the lamina papyracea. Here the ethmoidal infundibulum is closed superiorly by a blind pouch called the recessus terminalis (terminal recess). In this case the ethmoidal infundibulum and the frontal recess are separated from each other so that the frontal recess opens into the middle meatus medial to the ethmoidal infundibulum, between the uncinate process and the middle turbinate. The route of drainage and ventilation of the frontal sinus run medial to the ethmoidal infundibulum.
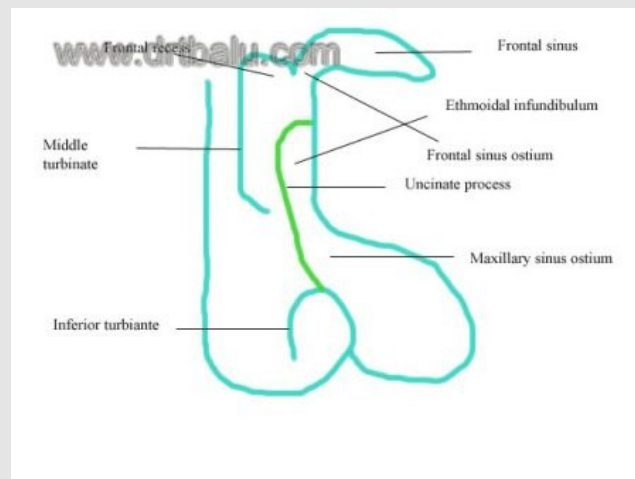
Type I uncinated insertion

Type II uncinate: Here the uncinate process extends superiorly to the roof of the ethmoid. The frontal sinus opens directly into the ethmoidal infundibulum. In these cases a disease in the frontal recess may spread to involve the ethmoidal infundibulum and the maxillary sinus secondarily. Sometimes the superior end of the uncinate process may get divided into three branches one getting attached to the roof of the ethmoid, one getting attached to the lamina papyracea, and the last getting attached to the middle turbinate.
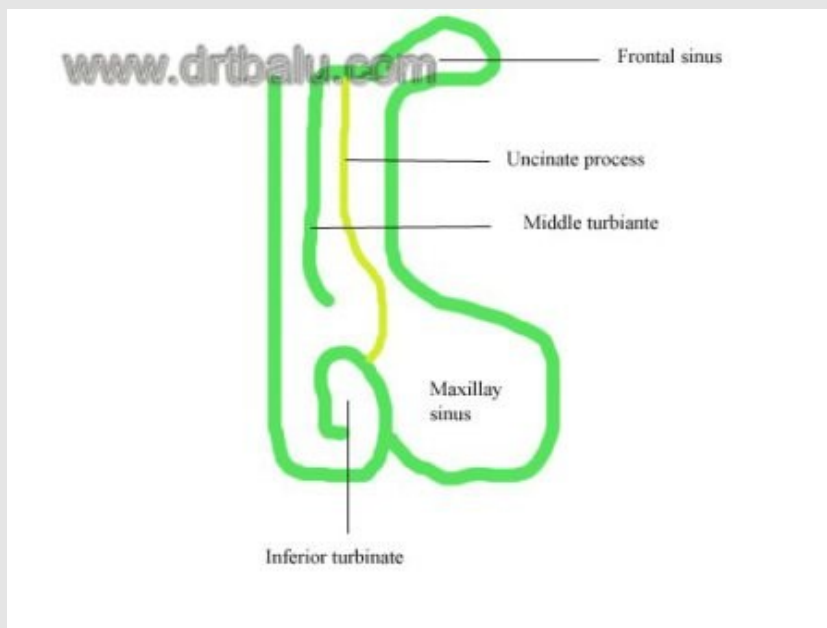

Figure showing Type II uncinate insertion

Type III uncinate process:

Here the superior end of the uncinate process turns medially to get attached to the middle turbinate. Here also the frontal sinus drains directly into the ethmoidal infundibulum. Rarely the uncinate process itself may be heavily pneumatised causing obstruction to the infundibulum.
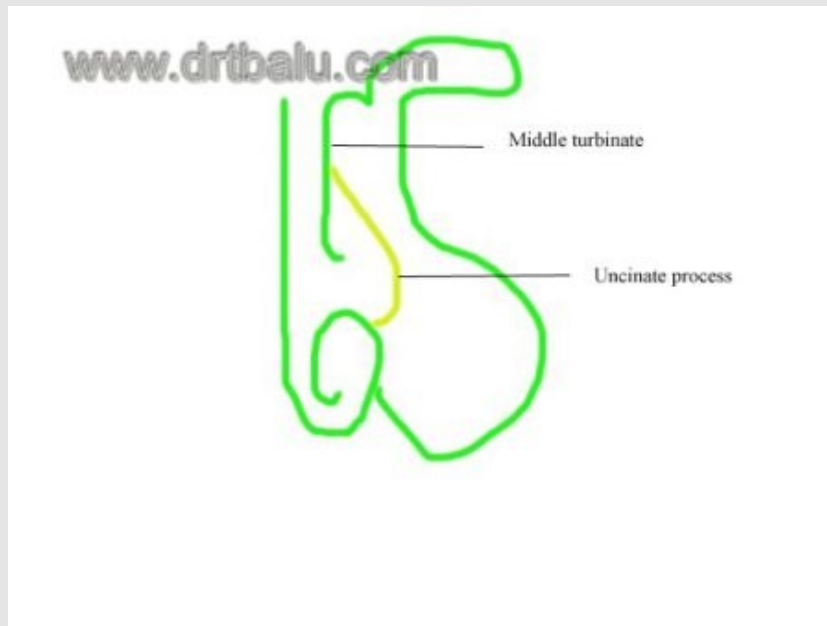
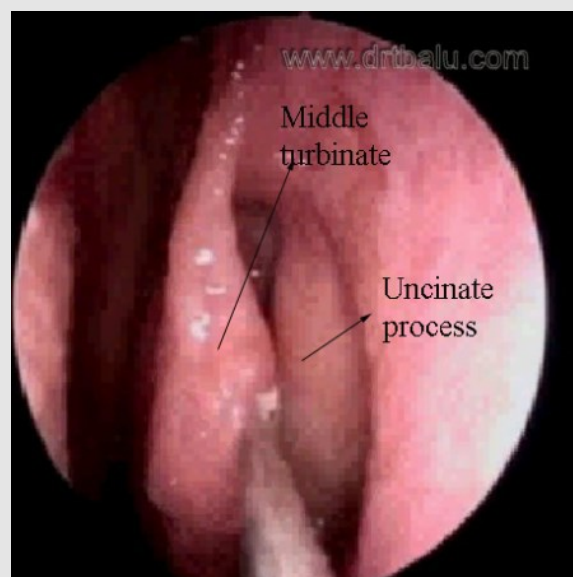Figure showing Type III Uncinate insertion

Figure showing Middle Meatus

Removal of uncinate process reveals the natural ostium of the maxillary sinus. This is another vital landmark in the lateral nasal cavity. The superior wall of the natural ostium of the maxillary sinus is at the level of floor of the orbit. Agger nasi: This is a Latin word for "Mound". This area refers to the most superior remnant of the first ethmoturbinal which presents as a mound anterior and superior to the insertion of middle turbinate. Depending on the pneumatisation of this area may reach up to the level of lacrimal fossa thereby causing narrowing of frontal sinus outflow tract. Ethmoidal infundibulum: is a cleft like space, which is three dimensional in the lateral wall of the nose. This structure belongs to the anterior ethmoid. This space is bounded medially by the uncinate process and the mucosa covering it. Major portion of its lateral wall is bounded by the lamina papyracea, and the frontal process of maxilla to a lesser extent. Defects in the medial wall of the infundibulum is covered with dense connective tissue and periosteum. These defects are known as anterior and posterior fontanelles. Anteriorly the ethmoidal infundibulum ends blindly in an acute angle.

Bulla ethmoidalis: This is derived from Latin. Bulla means a hollow thin walled bony prominence. This is another landmark since it is the largest and non variant of the aircells belonging to the anterior ethmoidal complex. This aircell is formed by pneumatization of bulla lamella (second ethmoid basal lamella). This air cell appears like a bleb situated in the lamina papyracea. Some authors consider this to be a middle ethmoid cell. If bulla extends up to the roof of ethmoid it can form the posterior wall of frontal recess. If it does not reach up to the level of skull base then a recess can be formed between the bulla and skull base.

This recess is known as suprabullar recess. If the posterior wall of bulla is not in contact with basal lamella then a recess is formed between bulla and basal lamella. This recess is known as retrobullar recess / sinus lateralis. This retrobullar recess may communicate with the suprabullar recess.

Osteomeatal complex:

This term is used by the surgeon to indicate the area bounded by the middle turbinate medially, the lamina papyracea laterally, and the basal lamella superiorly and posteriorly. The inferior and anterior borders of the osteomeatal complex are open. The contents of this space are the agger nasi, nasofrontal recess (frontal recess), infundibulum, bulla ethmoidalis and the anterior group of ethmoidal air cells.

This is in fact a narrow anatomical region consisting of :

1. Multiple bony structures (Middle turbinate, uncinate process, Bulla ethmoidalis)

2. Air spaces (Frontal recess, ethmoidal infundibulum, middle meatus)

3. Ostia of anterior ethmoidal, maxillary and frontal sinuses. In this area, the mucosal surfaces are very close, sometimes even in contact causing secretions to accumulate. The cilia by their sweeping movements pushes the nasal secretions. If the mucosa lining this area becomes inflamed and swollen the mucociliary clearance is inhibited, eventually blocking the sinuses. Some authors divide this osteomeatal complex into anterior and posterior. The classic osteomeatal complex described already has been described as the anterior osteomeatal complex, while the space behind the basal lamella containing the posterior ethmoidal cells is referred to as the posterior ethmoidal complex, thus recognising the importance of basal lamella as an anatomical landmark to the posterior ethmoidal system.

Hence the anterior and the posterior osteomeatal complex has separate drainage systems. So when the disease is limited to the anterior compartment of the osteomeatal complex, the ethmoid cells can be opened and diseased tissue removed as far as the basal lamella, leaving the basal lamella undisturbed minimising the risk during surgery.

Hiatus semilunaris:

Lies between the anterior wall of the Bulla and the free posterior margin of the uncinate process. This is in fact a two dimensional space. Through this hiatus a cleft like space can be entered. This is known as the ethmoidal infundibulum. This ethmoidal infundibulum is bounded medially along its entire length by the uncinate process and its lining mucosa. The lateral wall is formed by the lamina papyracea of the orbit, with participation from the frontal process of the maxilla and the lacrimal bone. The anterior group of sinuses drain into this area. In fact this area acts as a cess pool for all the secretions from the anterior group of sinuses.
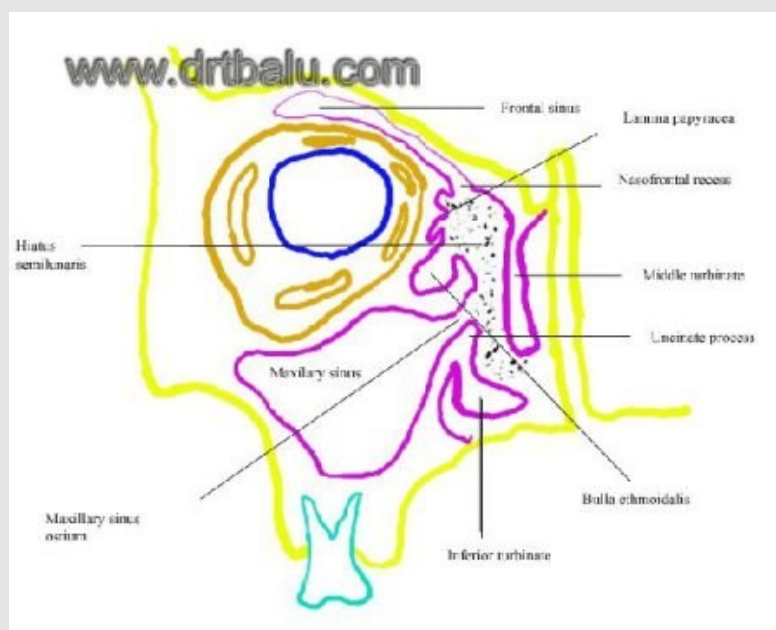

Figure showing Osteomeatal complex

Concha bullosa:

Sometimes middle turbinate may become pneumatised. This pneumatization is known as concha bullosa. This process of pneumatisation starts either from frontal recess or agger nasi air cells. This is usually considered to be a normal variant. Sometimes this pneumatisation may become so extensive that it could cause obstruction in Osteomeatal complex [8].

Coronal CT of sinuses showing Concha bullosa. Anterior ethmoid arteries are marked with red arrows

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CT Imaging of Nose and Sinuses

Introduction:

Galen was the first person to describe ethmoidal air cells. He was a famous Roman surgeon. According to Galen a good physician is also a good philosopher. He in fact considered himself to be a good philosopher than a good physician [1]. His figures based on meticulous dissection of human skull is considered to be fairly accurate even today. The anatomy of ethmoidal air cells is highly variable, it needs excellent imaging techniques to study. With the advent of CT imaging and image reconstruction technologies it is possible to precisely image this area and study the disorders involving it.
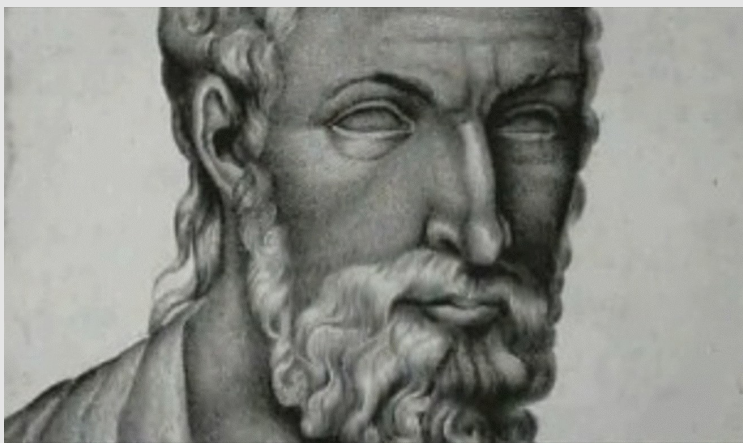

Image of Galen

Leonordo davinci in 1489 first described maxillary sinus [2]. He was actually an anatomist and painter unsurpassed. More famous for his paintings his contributions to the field of human anatomy cannot be underestimated. He was given special permission to dissect human corpses at the Hospital of Santa Maria Nuova Florence. His anatomy drawings are fairly accurate even by present day standards.

Sphenoid sinus was first described by Jacopo Berengario da Carpi [3] in 1521. His book titled "Anatomia Carpi" was considered to be the best. It was Coiter who introduced anatomists to the presence of frontal air cells. This feat actually happened sometime during the 16th century. The credit for the most modern description and depiction of paranasal sinuses should go to Emil Zuckerkandl. This 19th century anatomist's description is still considered to be accurate. This Hungarian anatomist really set the standard for present day anatomists to follow.

Leonordo davinci

The development of first modern CT scanner was started in 1967 by Godfrey Hounsfield of EMI Corp.

Routine use of CT scan has helped the surgeon to understand the complex anatomy of paranasal sinuses. CT scan in the present day context has become a virtual road map during endoscopic sinus and skull base surgeries. It should be borne in mind that anatomy of ethmoids and other sinuses are highly variable and it is virtually impossible to take into consideration all these variations during endoscopic sinus surgical procedures. A road map would definitely help the surgeon. Anatomy of nose and paranasal sinuses has virtually been rewritten after studying these radiological images.

Ideally when scanning nose and paranasal sinus it should be performed at least in two axis i.e. Axial and coronal. Cuts should be made every 3 mm in order to ensure that no structure is lost in between sections. Imaging should be performed using both soft tissue and bone windows. In order to derive maximum benefit from imaging studies it is imperative on the part of the surgeon to systematically evaluate the scan cuts. It is just like walking through the nose and various paranasal sinuses. Imaging studies of paranasal sinuses will also help in revealing potential sites of obstruction, enabling the surgeon to take preventive measures even before actual sinus ostium obstruction can set in. The ability of CT scan to optimally display bone, soft tissue and air makes it the most preferred imaging modality of nose and paranasal sinuses. It also clearly shows the fine bony details of sinus outflow tracts. Acute sinusitis is a clinical diagnosis, CT scan is recommended only if symptoms persist.

Portrait of the great Emil Zuckerkandl

Using intravenous contrast agents before performing actual imaging of paranasal sinuses will help in delineating soft tissue structures from bones. This study also helps in assessing the vascularity of the tumor. Contrast imaging is a must while evaluating patients with tumors involving nose and paranasal sinuses [4].

As far as inflammatory lesions of paranasal sinuses are concerned plain imaging would suffice. Elderly patients find it difficult to assume prone position for prolonged duration of time which is a must for producing coronal cuts. These patients will benefit from computer generated reconstructed coronal images from thin axial sections. For generating reconstructed coronal images 2 mm axial cuts is a must. It is always optimal to defer imaging in patients who have suffered acute episodes of sinus infections. The optimal period of wait for these patients before under going CT scans of nose and paranasal sinuses should at least be about 6 weeks. Similarly patients suffering from chronic sinus infections / allergic sinusitis / nasal polyposis should receive maximal medical therapy for at least a period of 3 weeks before subjecting them to imaging. Screening imaging of paranasal sinuses happens to be a cost effective way of imaging paranasal sinuses. In screening imaging thicker axial cuts (5-10mm) are taken. If screening reveals any pathology involving sinuses then regular imaging can be performed in these patients.

Currently available spiral CT scanners has really shortened the scanning time. It is possible to perform 0.5 mm cuts using these advanced scanning system.

Window setting before imaging:

CT scanner determines the amount of x-rays absorbed by each and every element in a plane of tissue. This detail is faithfully represented by a pixel on the video display. The amount of x-rays absorbed is measured in Hounsfield units. This unit of measurement was developed by Sir Godfrey Hounsfield who used radio density of water as a reference zero point and air at -1000. This scale extends in a positive direction to about +4000 which represents very radio dense metals.

CT scan video display will have two numbers displayed:

1. Window width (W)

2. Window level (L)

Window width:

This value describes the range of Hounsfield units displayed. The maximum window width possible is usually about 2000 HU. One point to be remembered is that human eyes are not capable of seeing and differentiating this many shades. In fact it can discriminate only about 16 shades of gray. Hence the window width value is divided usually by 16, and each of these groups of values are converted to one of 16 shades of gray. The lowest Hounsfield numbers in the window range are shown as black and the highest are white.

Window level:

This value is the Hounsfield number in the center of the window width. These two settings are indicated as W/L settings. On display screens the window width increases as the mouse is dragged to the right and the value decreases as the mouse is dragged down.

When performing CT imaging of abdomen which contains mostly soft tissue which are just a little denser than water having Hounsfield values between 0-100. Typical W/L setting would be 350/50. 350 different shades of gray will be displayed centered around a density of 50 HU. Each difference of 22 HU will show up as a different shade of gray.

Substance	HU
Air	- 1000
Lung	-700
Soft Tissue	-300 to—100
Fat	-84
Water	0
CSF	15
Blood	+30—+45
Muscle	+40
Bone Cancellous	+700
Dense Bone	+3000

Table showing radio densities of various body structures

Role of CT imaging for Endoscopic Sinus Surgeon

Introduction:

CT scan of nose and sinuses serves as a road map for the surgeon. For nose and sinus imaging scanning should include coronal and axial cuts ideally 3mm apart. If thinner axial cuts are performed it would facilitate accurate sagittal reconstruction. Highly variable anatomy of lateral nasal wall makes its imperative that these images be studied before the procedure. The timing of CT imaging has a very important role in deciding whether the pathology is irreversible. Surgical management is indicated only for irreversible diseases. At least a 6 week interval should be allowed to elapse before ordering CT imaging of sinuses [1]. Injecting contrast before scanning could help in better delineation of soft tissues and vascular lesions. Contrast CT scans are useful in evaluating neoplastic lesions. [2] Bone window scans are very useful in studying the bony anatomy of nose and sinuses.

Patient Positioning:

Axial views : Patient's hard palate is placed perpendicular to the CT scanner table. While capturing the images it should be ensured that the external auditory canal is in line with the inferior orbital rim.

Coronal views: While taking coronal images the gantry is placed perpendicular to the patient's hard palate. Misalignment / rotation can cause distortion of normal anatomy.

Screening CT scans:

5 mm cuts are ideal for rapid screening of patients. This not only reduces the scanning time but also reduces unnecessary radiation exposure to the patient. To be successful the screening CT protocol should meet the criteria of acceptability, reliability and validity. [3]

Advantages of Screening CT

1. Simple and inexpensive

2. Non invasive

3. Well tolerated by the patient

4. Can easily identify obstructions at the level of infun-
    dibulum

Indications of screening CT [4]:

1. The disease should be amenable to screening

2. It should be acceptable, reliable and easy to validate

3. Highly accurate confirmatory test should be available

4. There is efficacious means of treatment available for the disease identi-
    fied by screening

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Coronal and Axial CT imaging
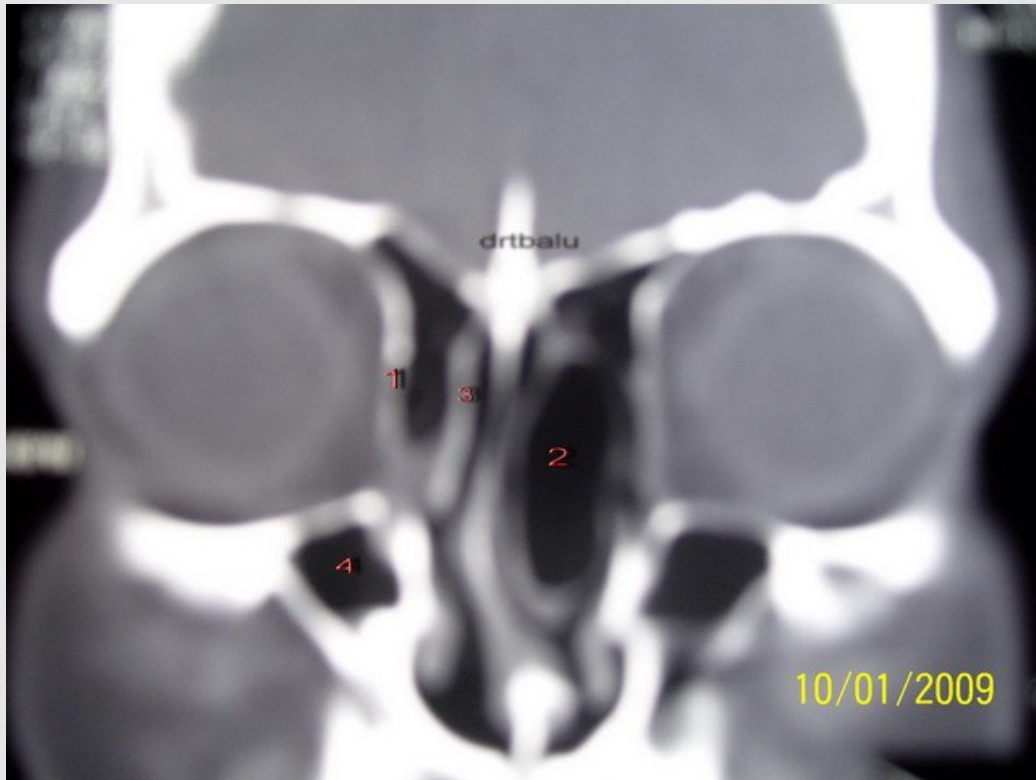
Image showing Coronal CT scan

1.   Lamina papyracea

2.   Concha Bullosa

3.   Right Middle turbinate

4.   Right maxillary sinus

With the advent of Endoscopic sinus surgery Coronal CT scans of paranasal sinuses has assumed importance because of the necessity to image osteo meatal complex [1.] Coronal Imaging of nasal sinuses has become mandatory before performing endoscopic sinus surgery because of its ability to show surgeon's view of the area. Coronal sections cannot clearly provide information about structures like basal lamella which lies parallel in this view. Only a scan performed in the axial plane will be able to demonstrate this area clearly.

Axial scan is better than coronal in visualizing the following areas [2]:

1. Posterior wall of frontal sinus

2. Bony wall between posterior ethmoid and sphenoid sinus

3. Pterygomaxillary fissure and pterygopalatine fossa
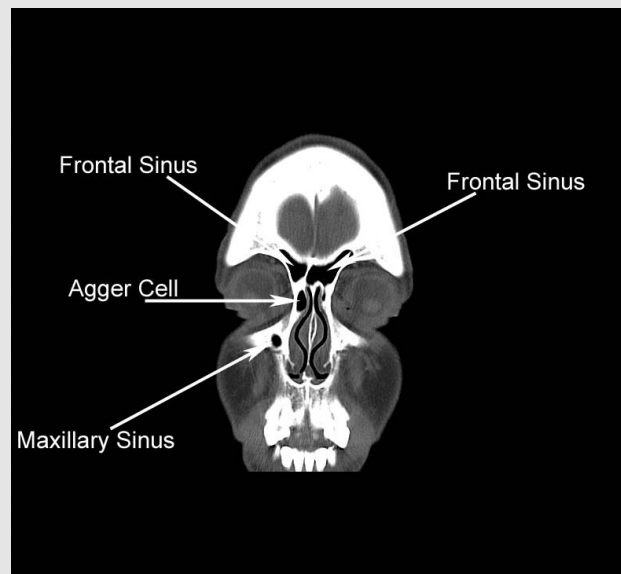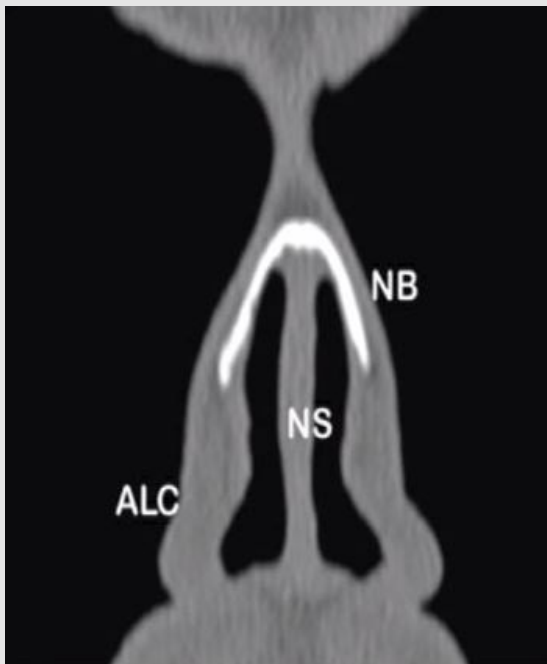
Normal coronal view anterior cuts

In the anterior cut nasal bones become visible. Normal gothic arch formed by the nasal bones should be looked for.   This gothic arch is distorted in fractures involving nasal bones.

Alar cartilages become visible. Nasal septum could also be seen. Frontal sinus is appearing. Just below the frontal sinus agger cell could be identified. Maxillary sinus could be seen appearing. CT scan should ideally be read from the first cut. CT scan should be read on a cut to cut basis. Not even a single cut should be missed. All the anatomical landmarks should be identified before dwelling in to the pathological changes.
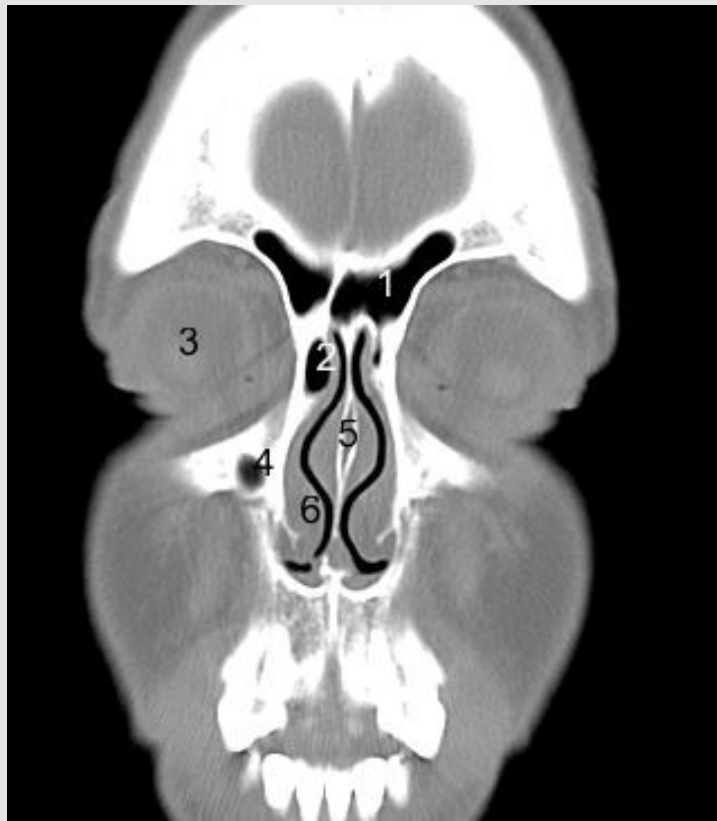
Coronal CT nose and sinuses anterior cut structures:

1. Frontal sinus

2. Agger Nasi

3. Orbit

4. Maxillary sinus

5. Nasal septum

6. Inferior turbinate

Nasal septum appears boggy. The term septal turbinate [3] is used to describe this type of nasal septum. This is a normal anatomical variant.
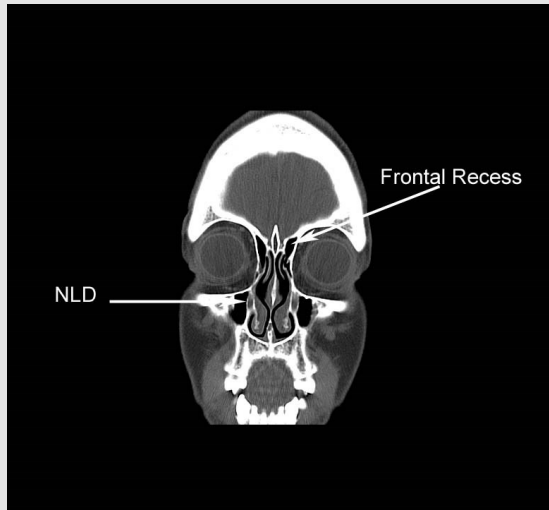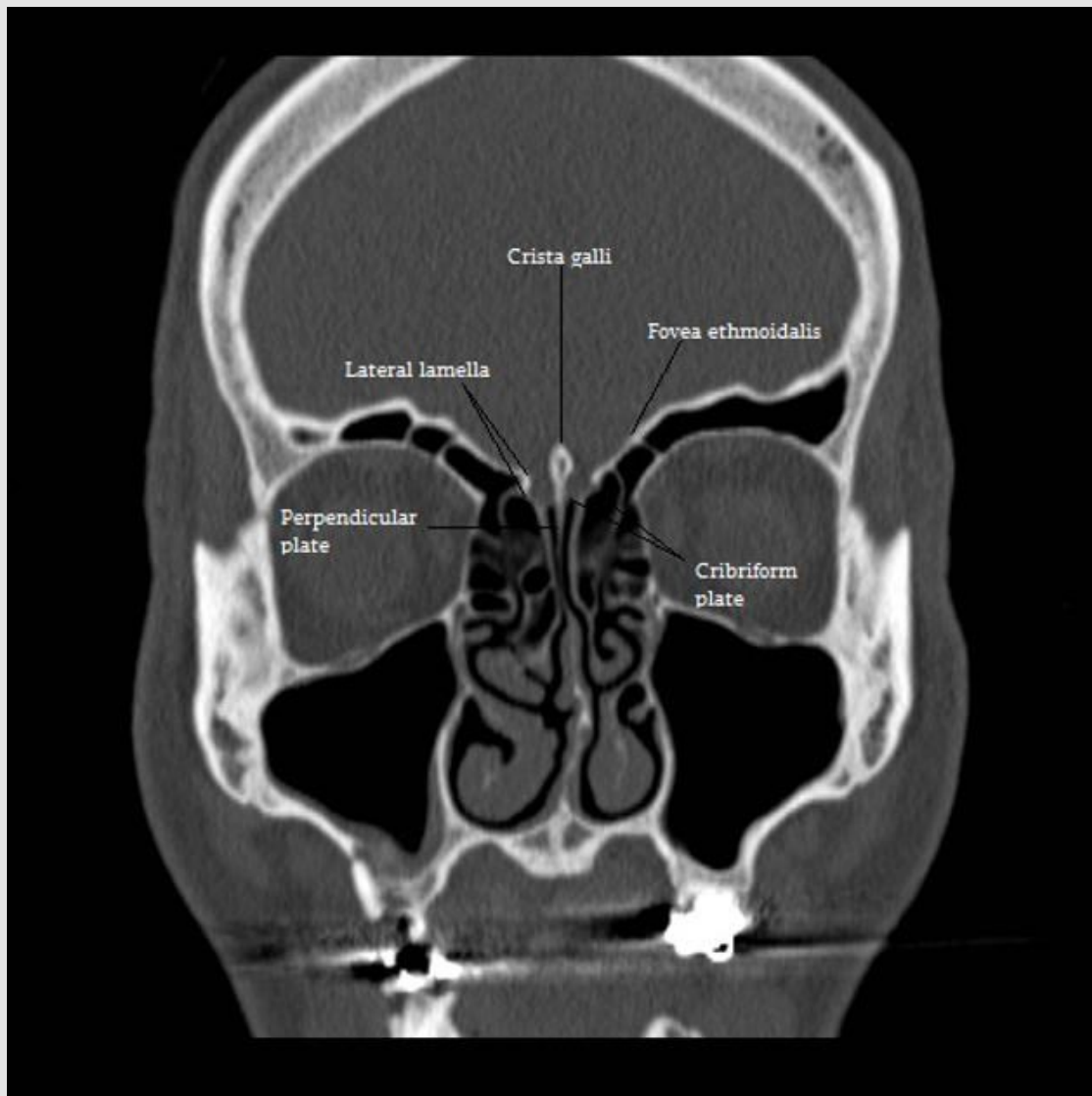
Coronal CT nose and sinuses at the level of frontal recess. Structures seen in this cut include naso lacrimal duct (NLD), inferior turbinate, frontal recess, and middle turbinate
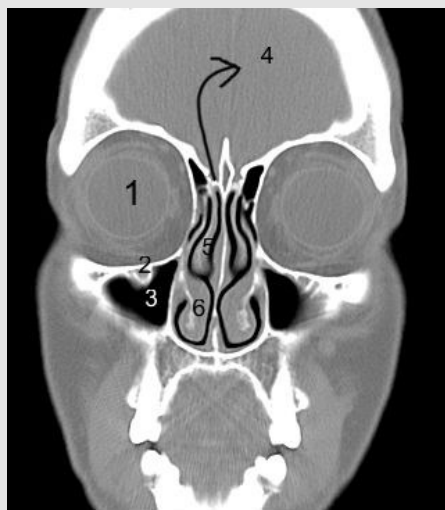
Coronal CT nose and sinuses showing:

1. orbit
2. Inferior orbital nerve
3. Maxillary sinus
4. Cribriform plate
5. Middle turbinate
6. Inferior turbinate

Coronal CT nose and sinuses showing cribriform plate area and fovea ethmoidalis

Keros classification of depth of olfactory fossa:

The depth of olfactory fossa is determined by the height of lateral lamella of the cribriform plate. Keros [4] classified this depth into three categories.

Type I : Depth of 1-3 mm

Type II : Depth of 4-7 mm (commonest)

Type III : Depth of 8-16 mm (rare)

Type III exposes more of thin lateral lamella of cribriform plate making this area more susceptible to injury during endoscopic sinus surgery.
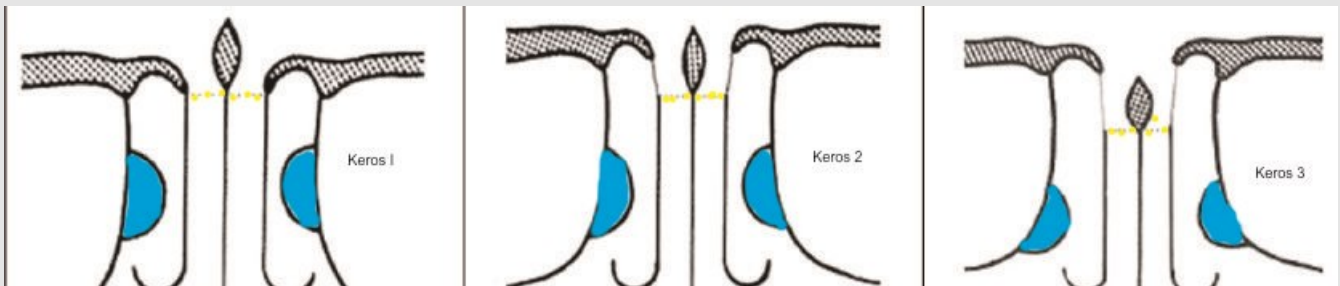
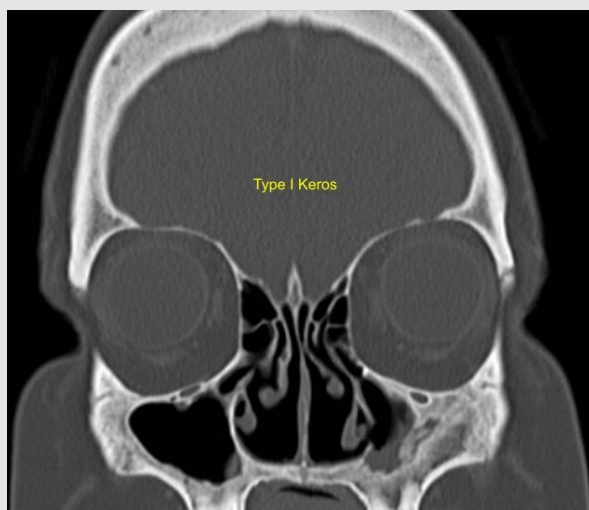Diagrammatic representation of Keros classification
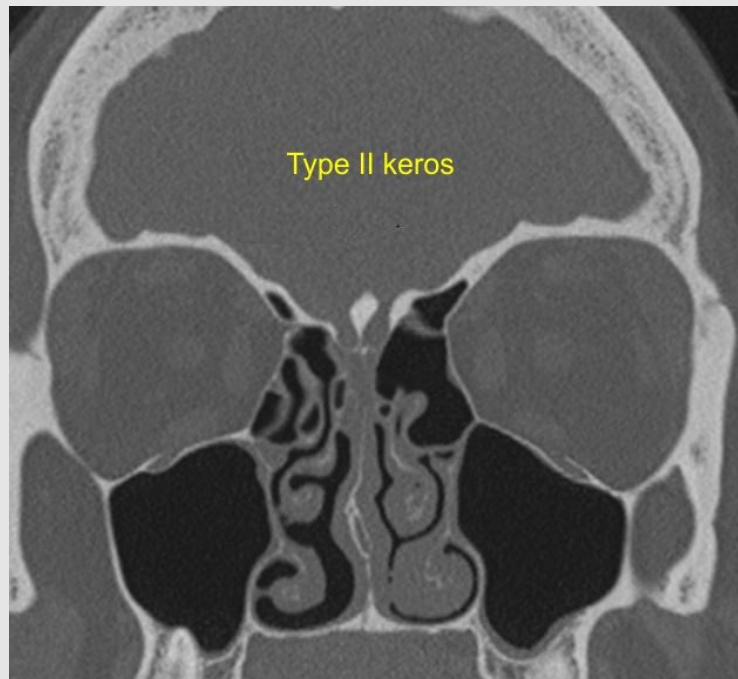

Image showing Keros type I classification

Image of Coronal CT nose and sinuses showing Type II keros skull base
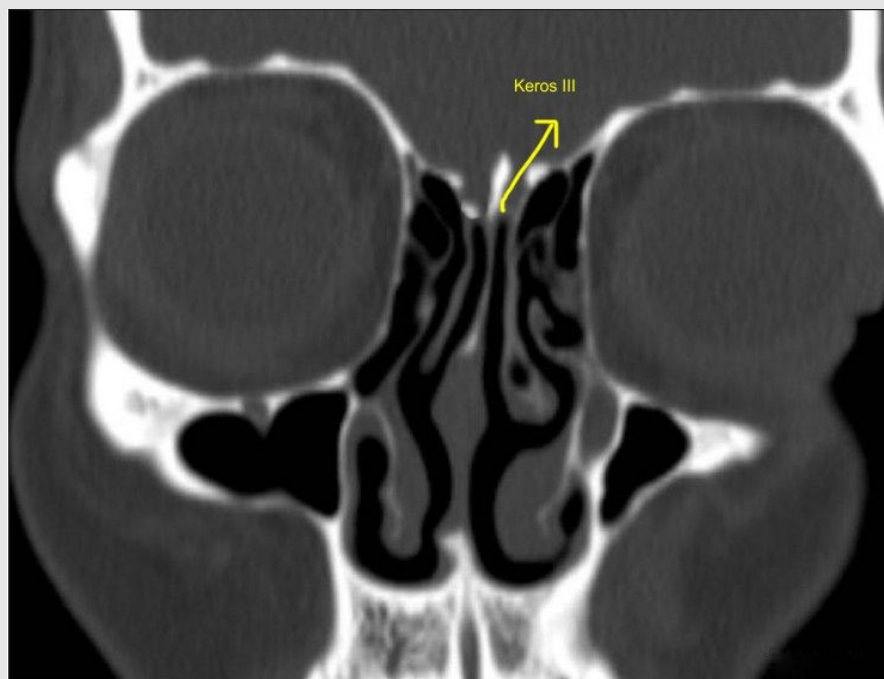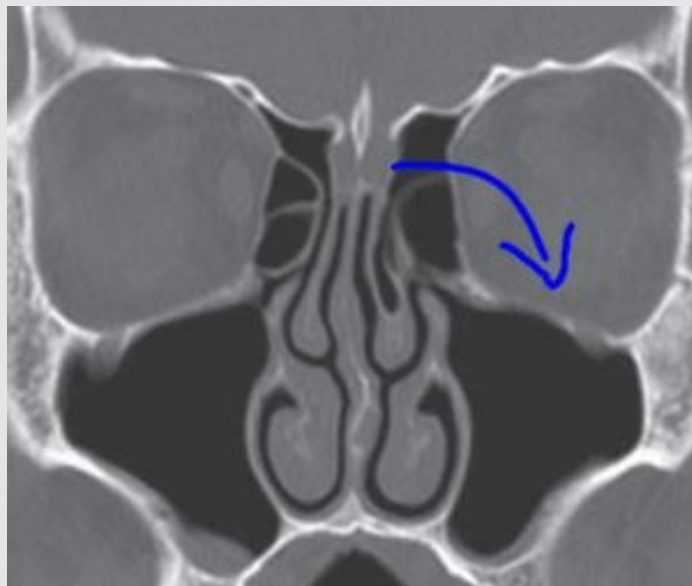

Image showing Keros Type III skull base

Anatomy of skull base is highly variable because of variations of ethmoid sinuses. Evaluation of roof of ethmoid and skull base will help in preventing complications like CSF leak following routine endoscopic sinus surgery [5]. Coronal CT images are best suited for this evaluation. Studies reveal that the area at risk during surgery is not the highest point of the ethmoid sinus formed by fovea ethmoidalis, but the lateral lamella of cribriform plate in the region of olfactory sulcus [6]. It is precisely here the anterior ethmoidal artery is found coursing further weakening the area.

Coronal CT image showing type III keros. Site indicated by the arrow is the most vulnerable area to injury during surgery. In this case even a small manipulation of middle turbinate is sufficient to cause skull base breach and CSF leak. Prior knowledge of this anatomic variation will prevent damage to this area.

Ethmoid air cells:

This area is highly variable. Ethmoid sinus consists approximately 7-15 cells with highly variable pneumatization patterns. For sake of better understanding this area is divided into:

1. Anterior ethmoidal air cells—Draining into middle meatus
2. Middle ethmoidal air cell (Bulla ethmoidalis) - This is constantly seen in almost all individuals
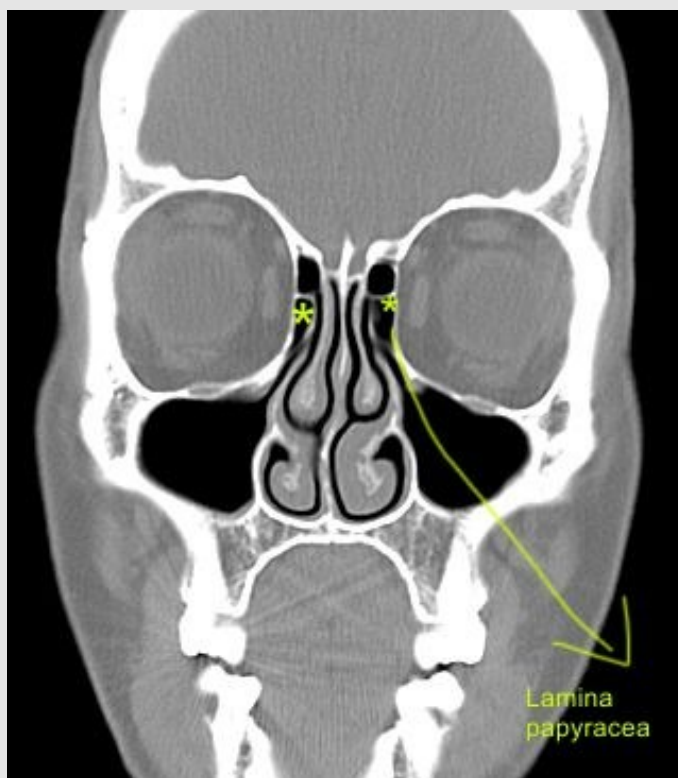3. Posterior ethmoidal air cells—These cells drain in to the sphenoethmoidal recess

Image of coronal CT nose and sinuses showing Bulla ethmoidalis (*) and

Lamina papyracea

Basal lamella:

This is the horizontal portion of middle turbinate which separates anterior ethmoidal air cells from posterior ethmoid group. Laterally basal lamella is attached to lamina papyracea. In the vertical axis the basal lamella is attached superiorly to anterior skull base. The insertion of middle turbinate gives rise to this unique anatomy.

Anatomically middle turbinate can be divided into 3 portions [7]. All these portions lie in 3 different planes.

Anterior portion: Lies sagittally getting attached to the skull base at the lateral edge of lamina cribrosa.

Middle portion: This portion lies almost in the frontal plane, and gets attached to the lamina papyracea.

Posterior portion: Is almost horizontal and gets attached to lamina papyracea.

The stability of middle turbinate is dependent on its fixation in these three planes.

Double middle turbinate:

This is actually not a true variant. This was first described by Kaufmann [9]. This is actually is a medially bent uncinate process curving out of the middle meatus like the brim of a hat.

Middle turbinate pneumatization:

Nasal turbinates develop as outgrowths arising from the lateral nasal wall known as ethmoturbinals [8]. The middle turbinate arises from the third ridge. Variations in pneumatization of these ethmoturbinals may lead to anatomical variations within the bony structures of ethmoidal labyrinth.

Bolger [10] classified pneumatization of middle turbinate into three types:
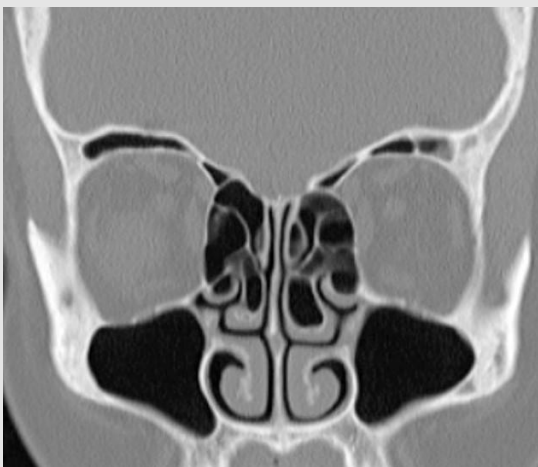
Lamellar type pneumatization: This involves pneumatization of vertical lamella of middle turbinate.

Bulbous type pneumatization: Involves pneumatization of inferior portion of middle turbinate

Extensive pneumatization: Involves pneumatization of both lamellar portion and inferior portion of middle turbinate. It is also known as Concha bullosa.

CT image showing huge concha bullosa of middle turbinate. It could be seen encroaching into the maxillary sinus

CT image showing bulbar pneumatization of middle turbinate
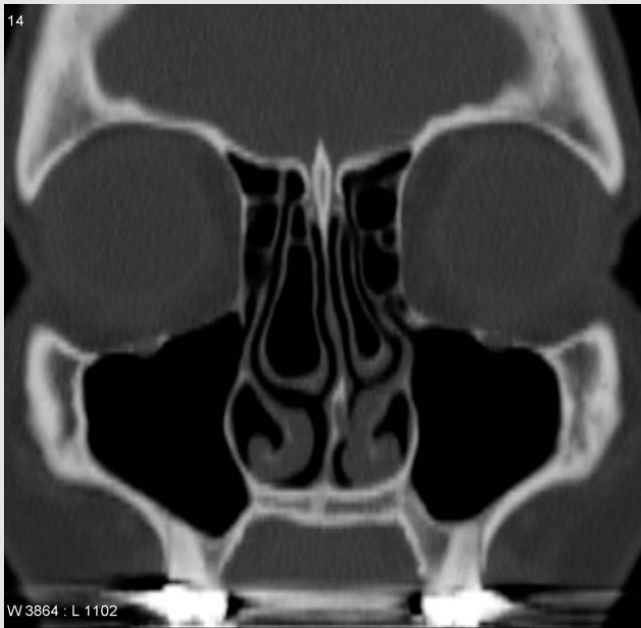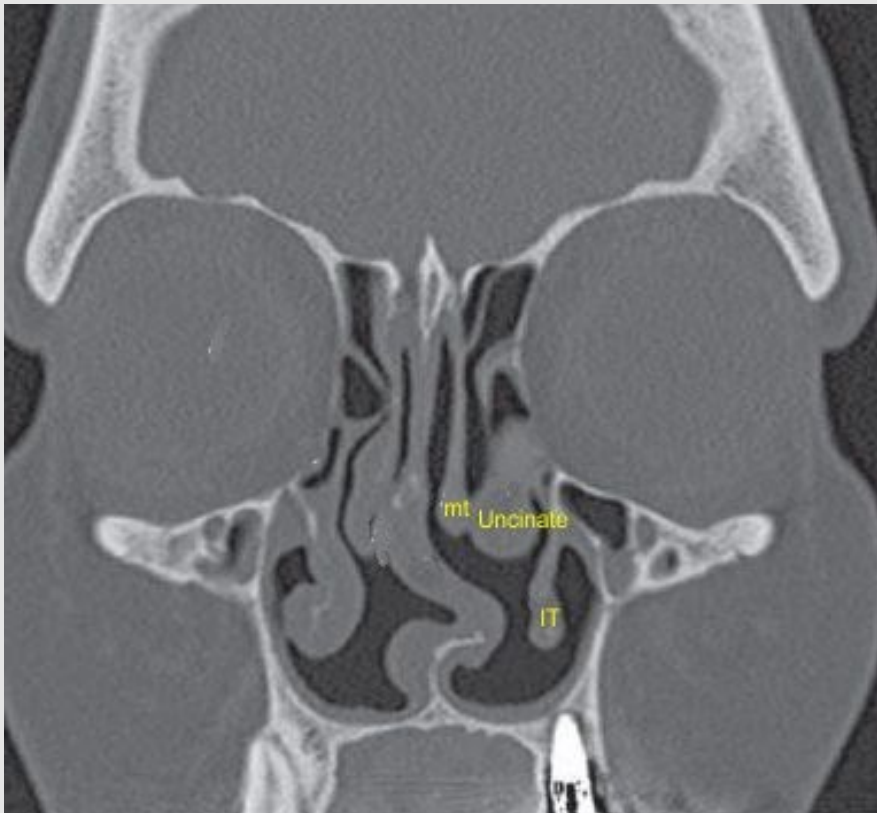
CT image showing lamellar type pneumatization

Figure showing Kauffmann's double middle turbinate which is actually a medially deviated uncinate process

Anterior ethmoidal artery:

Anatomical knowledge of anterior ethmoidal artery is vital during endoscopic sinus procedures if complications are to be minimized. During its course the anterior ethmoidal artery crosses three cavities (the orbit, ethmoidal labyrinth and anterior cranial fossa of skull). The anterior ethmoidal artery enters the olfactory fossa through the lateral lamella of cribriform plate along the anterior ethmoidal sulcus. The bone over the anterior ethmoidal sulcus is very thin and is at risk during endoscopic surgery. The relationship of the anterior ethmoidal artery to the roof of the ethmoid is highly variable and is at risk during endoscopic sinus surgeries. Identification of this artery is important in identifying frontal sinus outflow tract and superior limits of skull base.

Areas supplied by anterior ethmoidal artery:

It supplies the anterior ethmoidal cells and the frontal sinus. As it courses along the olfactory fossa it gives rise to meningeal vessels. This artery also supplies the anterior third of nasal septum and lateral nasal wall.

Stamberger reported that anterior ethmoidal artery may be in direct contact with skull base. This is particularly true if the roof of the ethmoid sinus is low. In majority of cases he reported that a bony mesentery could connect the anterior ethmoidal artery to the skull base. He also reported that there could be a space of about 5 mm between the anterior ethmoidal artery and skull base.

According to Gotwal who extensively studied the course of anterior ethmoidal artery by viewing coronal CT scans of nose and sinuses found that the presence of a notch in the medial wall of orbit indicates the probable site of antrior ethmoidal foramen. He also suggested that the presence of focal funneling in the olfactory fossa could indicate the probable position of anterior ethmoidal artery.

Coronal CT showing a dimple in the medial wall of orbit indicating probable site of anterior ethmoidal artery
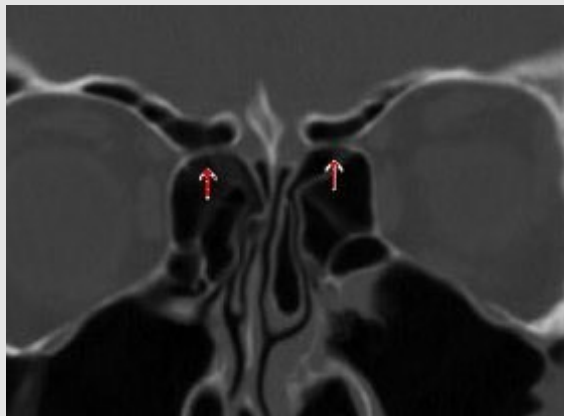
Coronal CT showing anterior ethmoidal canal coursing through anterior ethmoidal cells

Coronal CT showing anterior ethmoidal artery in skull base

It should be borne in mind that concha bullosa of middle turbinate is almost always associated with deviated nasal septum to the opposite side.

Septated concha bullosa:

Concha bullosa of middle turbinate may also be septated,. It was first described by Yanagisawa et al.[11] in 2008.

CT Image showing septated concha bullosa

Anatomical variations of middle turbinate include:

1. Pneumatization
2. Lateralization
3. Hypoplastic
4. Hypertrophic
5. Paradoxically curved
6. Bifurcate / trifurcate
7. Septate

CT scan of nose and sinuses should ideally help:

1. In establishing the anatomy of the area

2. In Identifying predisposing factors causing the problem

3. In identifying the disease process

4. In identifying surgical pitfalls

5. In surgical planning which could be customized to patient's needs

Axial CT imaging of nose and sinuses helps in demonstrating structures that lie parallel to the coronal plane. Most of the structures that separate various sinuses lie in this plane. These structures include:

1. Basal lamella

2. Anterior wall of sphenoid sinus

3. Third basal lamella

Nasolacrimal duct, olfactory groove and the optic nerve are clearly visible in both these sections. Anterior ethmoid arteries are clearly visible in the coronal scans only. It can be clearly demonstrated when they penetrate the lamina papyracea to enter the orbit.
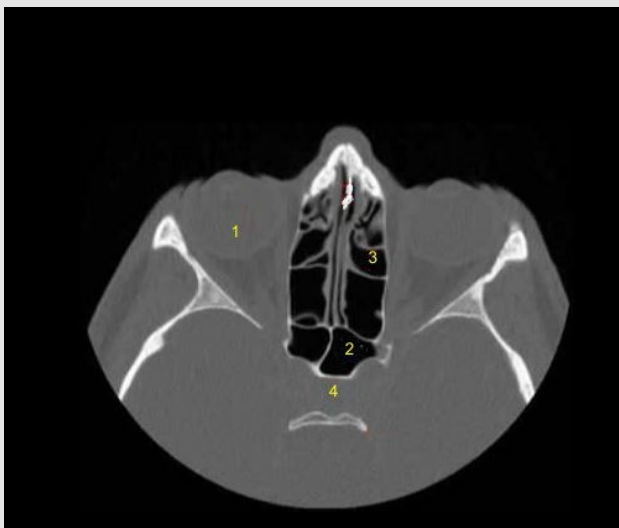
Axial CT showing 1. orbit, 2. Sphenoid sinus, 3. Ethmoidal air cells

4. Pituitary gland

Haller cell causing obstruction of Osteomeatal complex is clearly seen only in coronal scans. Axial scans do not display it clearly.
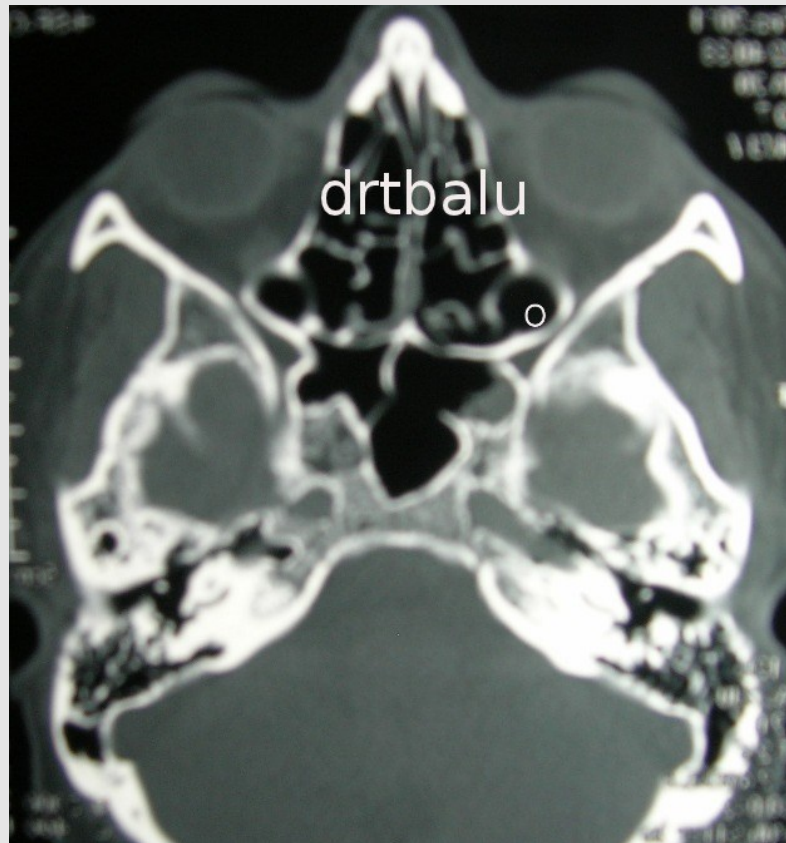
Axial CT showing Onodi air cell

To make up for the limitations of coronal scans a few axial cuts can be ordered. These discontinuous scans can only be useful for diagnostic purposes only. Surgery should not be ventured with these discontinuous scans as it would be catastrophic.

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Anatomical variations

Study of anatomical variations of nose and paranasal sinuses are rather important. Points to be borne in mind during the study include:

1. Anatomical variations are very common in this area

2. Majority of these variations are asymptomatic needs no intervention

3. Some of these variations can cause anatomical obstruction to critical drainage areas of paranasal sinuses. This becomes an indication for endoscopic sinus surgery

4. Some of these variations can cause cosmetic issues to the patient

Patency of drainage of nasal sinuses is rather important because the mucosal lining of nose and nasal sinuses (which is continuous in a physical sense) secretes about 1 litre [1]of mucous per day. This needs to be drained on a continuing basis. Obstruction to this process of drainage predisposes to chronic sinusitis.

Major anatomical variations leading to obstruction in the Osteomeatal complex area include:

1. Deviated nasal septum

2. Concha bullosa involving middle turbinate

3. Paradoxical middle turbinate

4. Infraorbital air cell (Haller cell)

Among these variations deviation of nasal septum happens to be the commonest one.
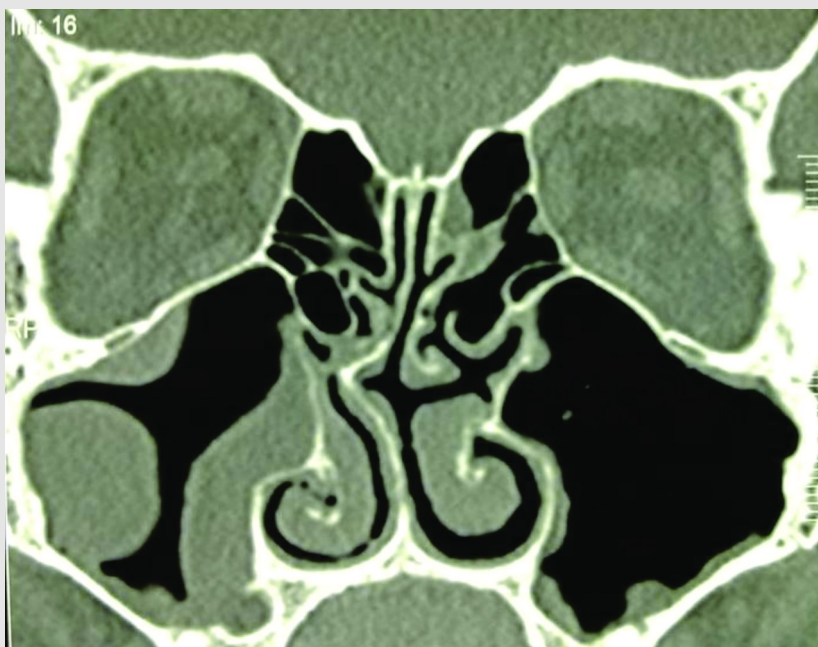
Deviated nasal septum:

Varying degrees of deviations involving nasal septum has been documented at birth. These deviations tend to accentuate as the child grows. [2] A dot central nasal septum is a clinical curiosity as it is very rare. Majority of deviations involving the nasal septum don't cause any symptoms [3].

Cottle's classification of septal deviation:

Cottle classified septal deviation into 3 types.

1. Simple deviation: Only a mild deviation of nasal septum with no symptoms of obstruction. This is the most common type seen.

2. Deviation with obstruction: Here deviation touches the lateral wall of nose, but on decongestion the turbinates shrink and improves the nasal airway

3. Impaction: Massive angulation of nasal septum with presence of spur.

Coronal CT image of nose and sinuses showing septal spur

Axial CT image of Nose and sinuses showing deviated nasal septum with spur

Nasal septal deviations are usually accompanied by contralateral compensatory hypertrophy of inferior turbinate. This is actually nature's attempt to reduce the size of enlarged nasal airway on the contralateral side due to septal deviation.

Axial CT image of nose and sinuses showing septal spur causing a reduction in the volume of maxillary sinus

Septal Body: (Septal turbinate) [4]

This is a widened area of nasal septum located superior to the inferior turbinate and anterior to the middle turbinate. It is composed of septal cartilage. Septal cartilage is thicker here than the other parts of nasal septum.   The mucosal covering of septal body is thicker than the other portions of nasal septum. This body is in intimate relationship to the internal nasal valve. It is suspected to play a role in the maintenance of nasal resistance.

Histologic criteria for the identification of septal body:

Septal body can be identified using the following Histologic criteria.

The lining epithelium is pseudostratified columnar epithelium with goblet cells.

1. The epithelium is 60 – 100 μm thick.

2. Many seromucinous glands are present

3. Numerous blood sinusoids are present

Most commonly is could be an incidental finding. On routine examination a septal body should be differentiated from high septal deviation.

Septal body should be included among the erectile tissues found in the nasal cavity. It should be managed in the same way as hypertrophied turbinates in cases of nasal obstruction caused by these structures. Its proximity to the internal nasal valve arouses the suspicion as the cause for nasal obstruction.

Septal turbinate has a tendency to shrink when packed with nasal decongestant impregnated roller gauze.
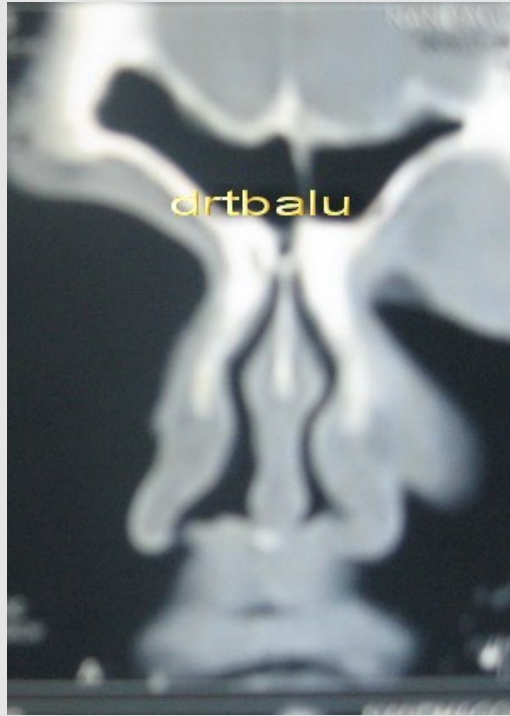
Coronal CT Nose and paranasal sinuses (anterior cut) showing septal body

In endoscopic examination appears as a prominence along the anterior and middle portion of nasal septum. This condition is usually misdiagnosed as high septal deviation. Palpation of the area usually clinches the diagnosis.

Nasal septal body when compared to inferior turbinate contain lesser amount of erectile tissue[5]and hence does not show the rapid expansile property of inferior turbinate. Even minimal changes in the size of the septal body can cause rapid increase in the nasal resistance.

Coronal CT image of nose and sinuses showing concha bullosa and high septal deviation on the opposite side
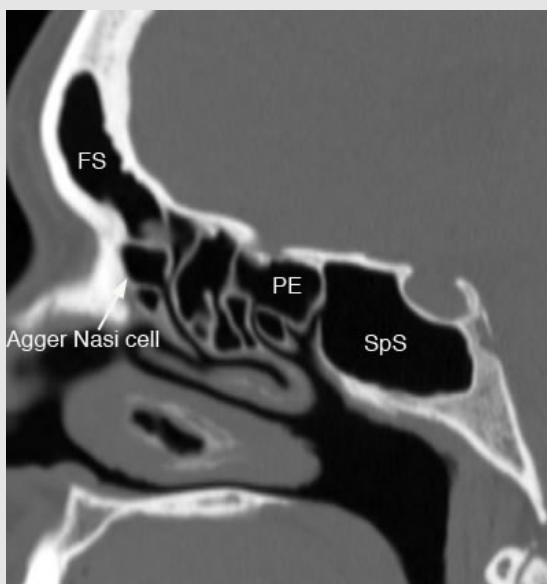
Agger Nasi cells:

This is the anterior most of ethmoidal air cells. It lies anterolateral and inferi-or to the frontoethmoidal recess. Endoscopically it lies anterior and above the attachment of middle turbinate. These cells are identifiable in about 90% of humans. It also serves as a vital landmark for frontal sinus ostium. En-largement of this air cell can lead to frontal sinusitis. This cell penumatizes first.
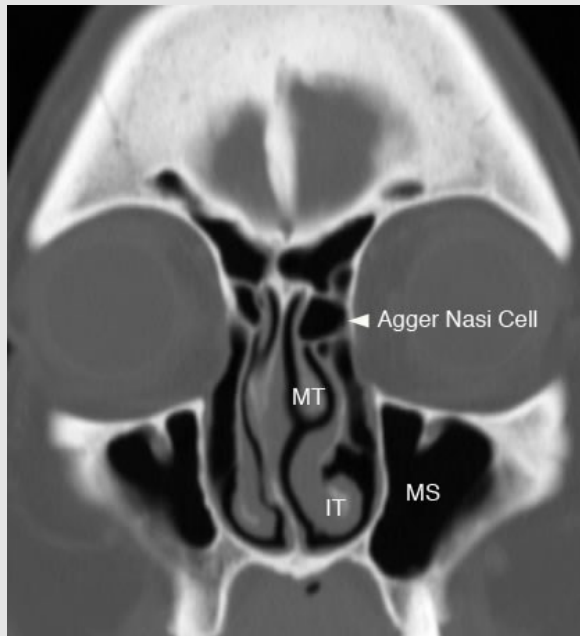
Coronal CT image of nose and sinuses show agger nasi air cell.

MT - Middle turbinate IT - Inferior turbinate MS - Maxillary sinus

FS - Frontal sinus

PE - Posterior ethmoid

SPS - Sphenoid sinus

CT nose and sinuses lateral reformatted view showing the relationship between agger-nasi and frontal sinus drainage pathway

Agger nasi air cell could pneumatize posteriorly towards the frontal recess area causing obstruction to drainage of frontal sinus. The interaction between the upper portion of uncinate process and agger nasi air cell is important in the understanding of frontal sinus drainage pathway. When agger nasi pneumatizes posteriorly it pushes the posterosuperior attachment of uncinate process backward to the lamina papyracea leading to the formation of terminal recess [6].
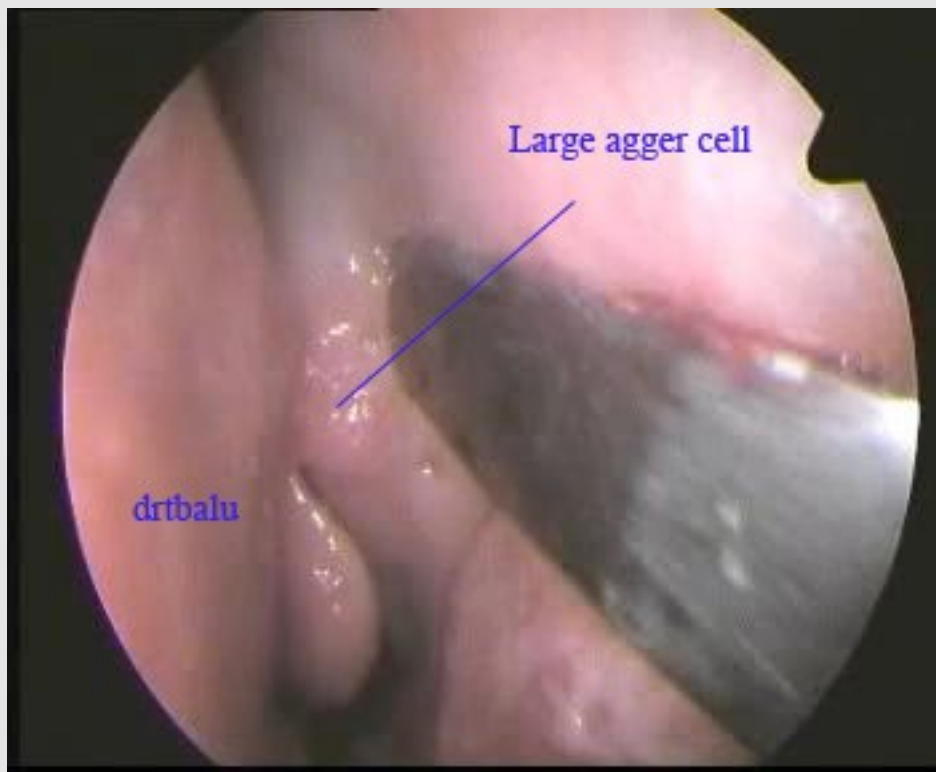

Figure showing Endoscopic view of Agger Nasi

Agger nasi cell abut the paper thin lamina papyracea. Any disease process affecting the lateral wall of agger nasi can spread to adjacent lacrimal sac causing epiphora and inflammatory conditions of lacrimal system.

Haller Cell:

These cells are also known as infraorbital ethmoidal air cells/ Maxillo ethmoid air cells [7]. These cells invariably extend into the inferomedial portion of orbital floor. These cells are commonly seen in 40% of patients [8]. This air cell is actually named after Albrect von Haller the Swedish Anatomist who described these air cells.
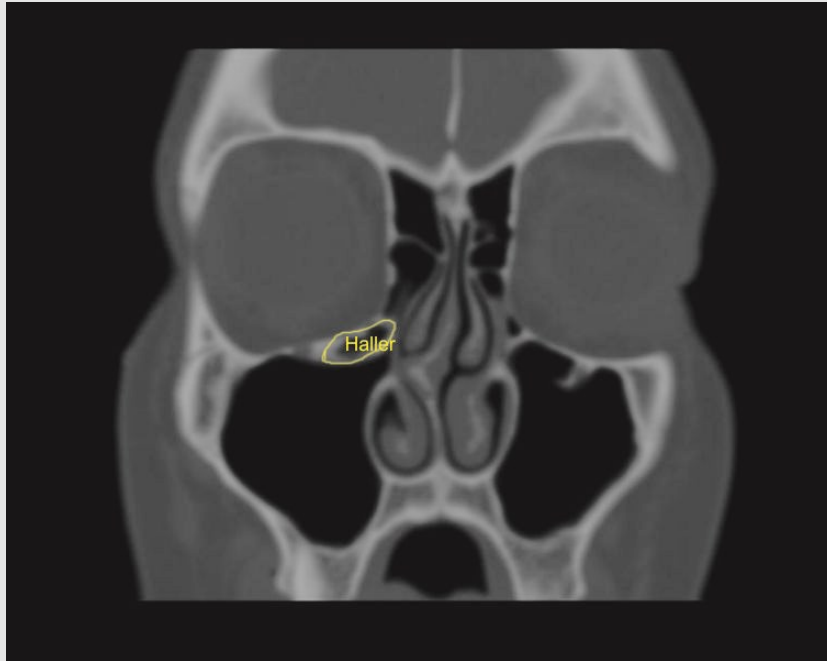
Coronal CT image of nose and sinuses showing Haller cell

In majority of patients Haller cells may be asymptomatic. [9].

Radiological classification of Haller cell:
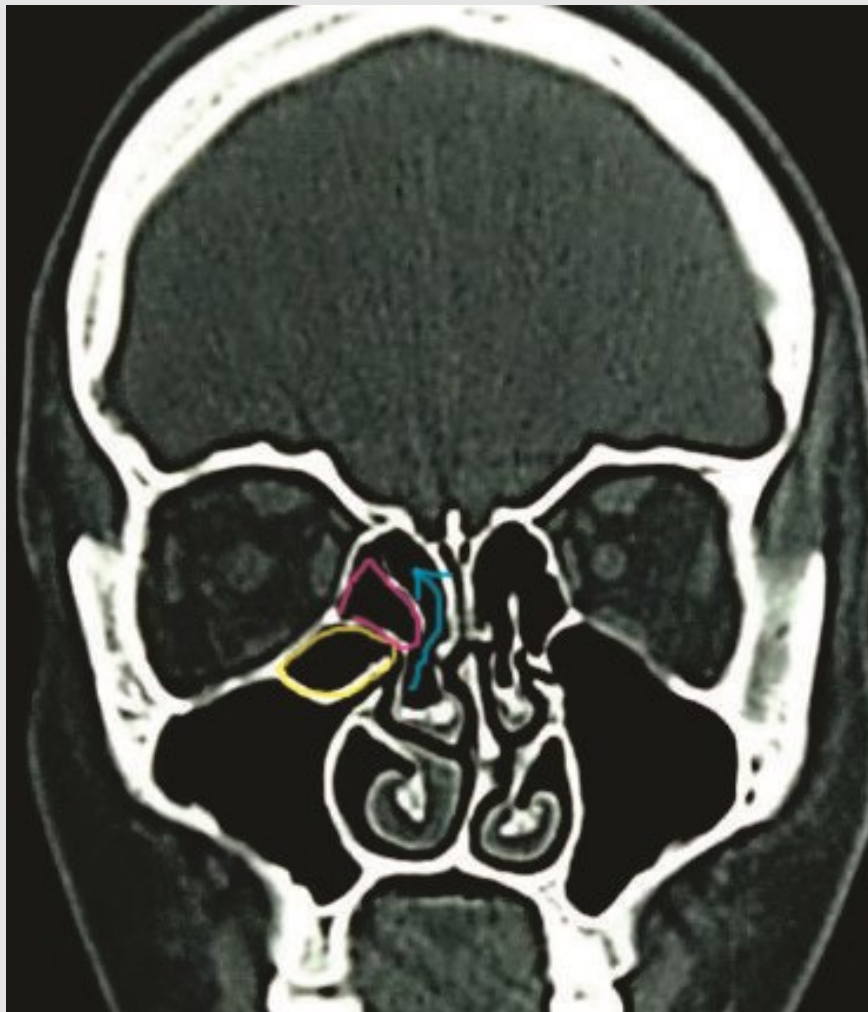
1. Small
2. Medium
3. Large

Image showing Haller cell as seen in Axial CT image of nose and sinuses
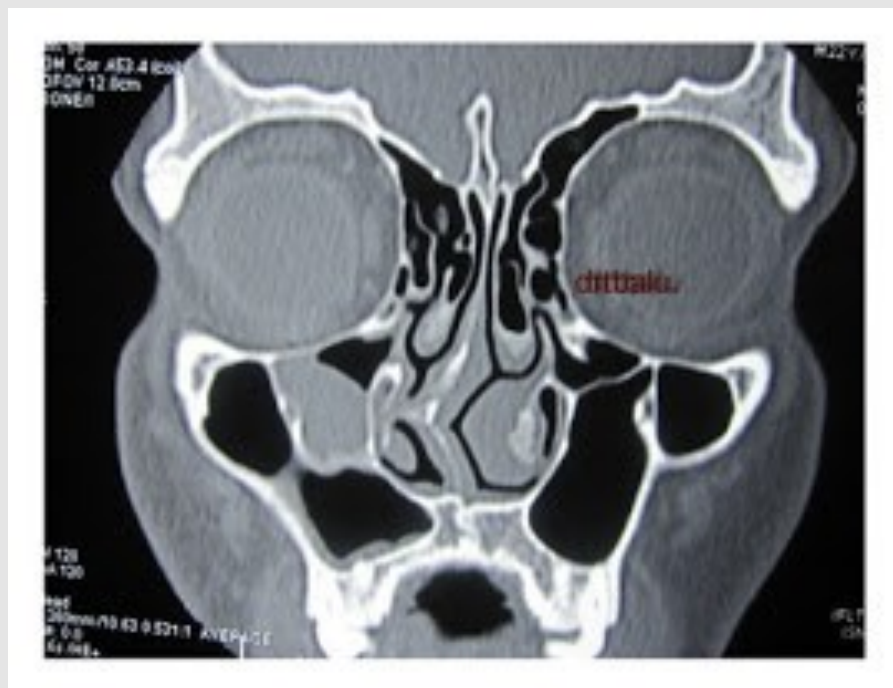
Coronal CT image of nose and sinuses showing large infected Haller cell

CT nasal sinuses lateral view showing infected Haller cell

Right posterior Haller cell with middle turbinate concha communicating with suprabullar recess

Paradoxical Middle turbinate:

Middle turbinate has a curvature. Normally the convexity of the curvature is towards the nasal septum. In paradoxically curved middle turbinate the convexity of the curvature is towards the middle meatus. This condition can cause narrowing of Osteomeatal complex area.
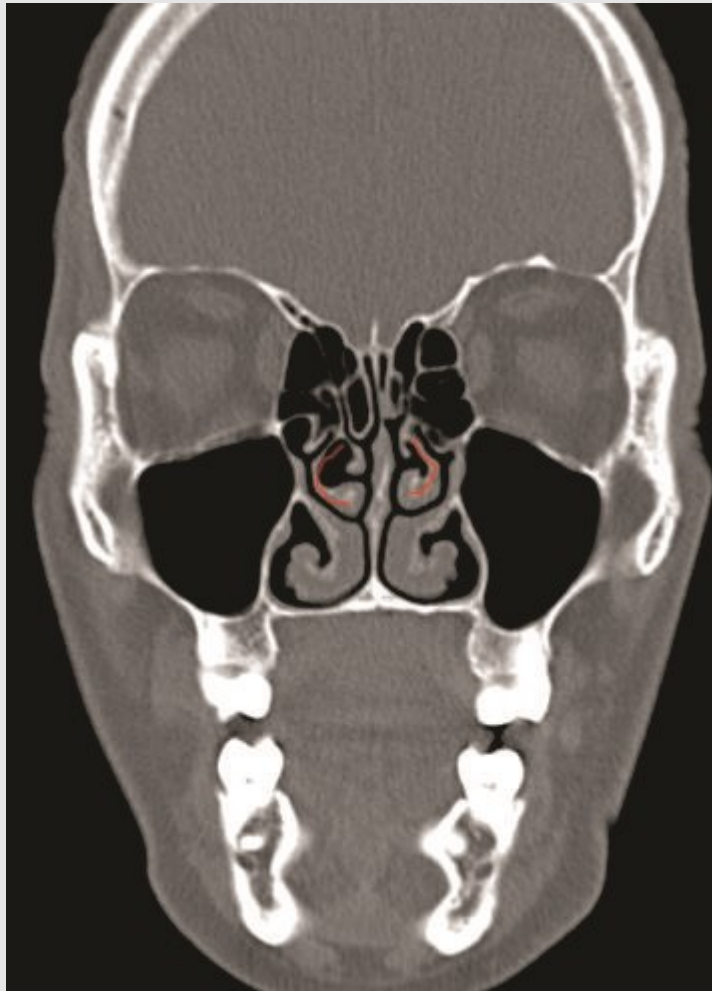
Coronal CT Image of nose and sinuses showing bilateral paradoxically curved middle turbinate

Ethmoid sinus:

This is situated lateral to the olfactory fossa, between lateral nasal wall and medial wall of orbit. This sinus is the most compartmentalized of all paranasal sinuses, hence it shows the maximum anatomical variations. At birth only a few ethmoid air cells are pneumatised, this number swells to 20 as adult hood is reached. For easy and better understanding ethmoidal labyrinth is divided by 5 obliquely directed parallel lamella.

1. First lamella (anterior lamella): This is the uncinate process, which embryologically corresponds to the basal lamella of first ethmoturbinal.

2. Second lamella: This is the ethmoid bulla (Bulla ethmoidalis). This is the most constant of all ethmoid air cells. According to Zuckerkandl [10] this is the largest of all anterior ethmoid air cells.

3. Third lamella: This is the most important. It is the basal lamella of middle turbinate separating anterior from posterior ethmoid air cells. This is the exact surgical posterior limit of anterior ethmoidectomy.

4. Fourth lamella: Is the basal lamella of superior turbinate

5. Fifth lamella: is the basal lamella of supreme turbinate

Coronal CT Nose and sinuses showing Uncinate process (Marked in green)

Uncinate Process:

The uncinate process is a wing or boomerang shaped piece of bone. It forms the first layer or lamella of the middle meatus [11]. It attaches anteriorly to the posterior edge of the lacrimal bone, and inferiorly to the superior edge of the inferior turbinate. Superior attachment of the uncinate process is highly variable, may be attached to the lamina papyracea, or the roof of the ethmoidal sinus, or sometimes to the middle turbinate. The configuration of the ethmoidal infundibulum and its relationship to the frontal recess depends largely on the behavior of the uncinate process. The uncinate process can be classified into 3 types depending on its superior attachment. The anterior insertion of the uncinate process cannot be identified clearly because it is covered with mucosa which is continuous with that of the lateral nasal wall. Sometimes a small groove is visible over the area where the uncinate attaches itself to the lateral nasal wall.
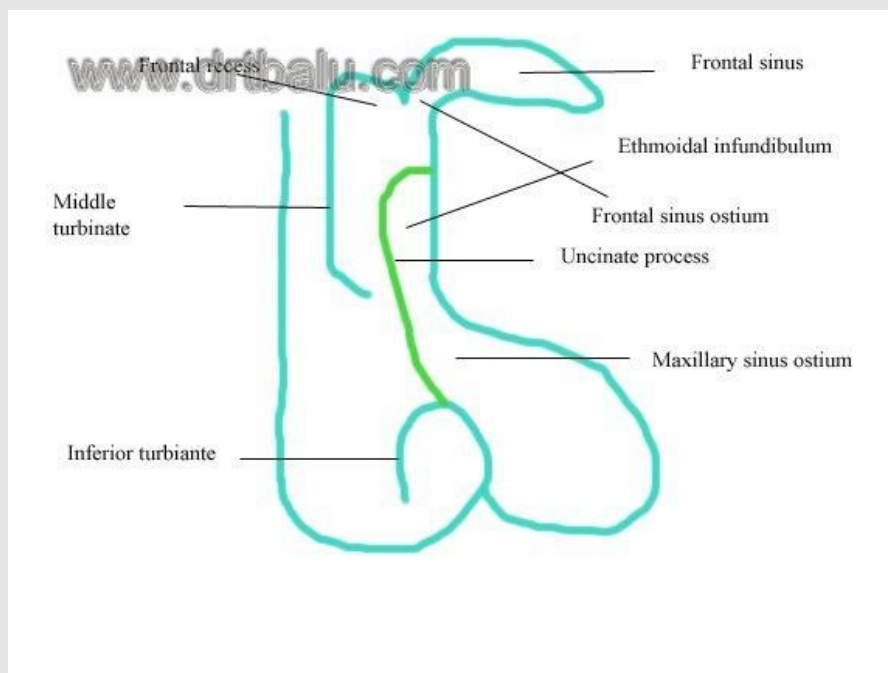
Type I Uncinate:

Figure showing Type I uncinate process

Here the uncinate process bends laterally in its upper most portion and inserts into the lamina papyracea. Here the ethmoidal infundibulum is closed superiorly by a blind pouch called the recessus terminalis (terminal recess). In this case the ethmoidal infundibulum and the frontal recess are separated from each other so that the frontal recess opens in to the middle meatus medial to the ethmoidal infundibulum, between the uncinate process and the middle turbinate. The route of drainage and ventilation of the frontal sinus run medial to the ethmoidal infundibulum.

Coronal CT nose and sinuses showing Type I uncinate

Type II Uncinate:

Here the uncinate process extends superiorly to the roof of the ethmoid. The frontal sinus opens directly into the ethmoidal infundibulum. In these cases a disease in the frontal recess may spread to involve the ethmoidal infundibulum and the maxillary sinus secondarily. Sometimes the superior end of the uncinate process may get divided into three branches one getting attached to the roof of the ethmoid, one getting attached to the lamina papyracea, and the last getting attached to the middle turbinate.
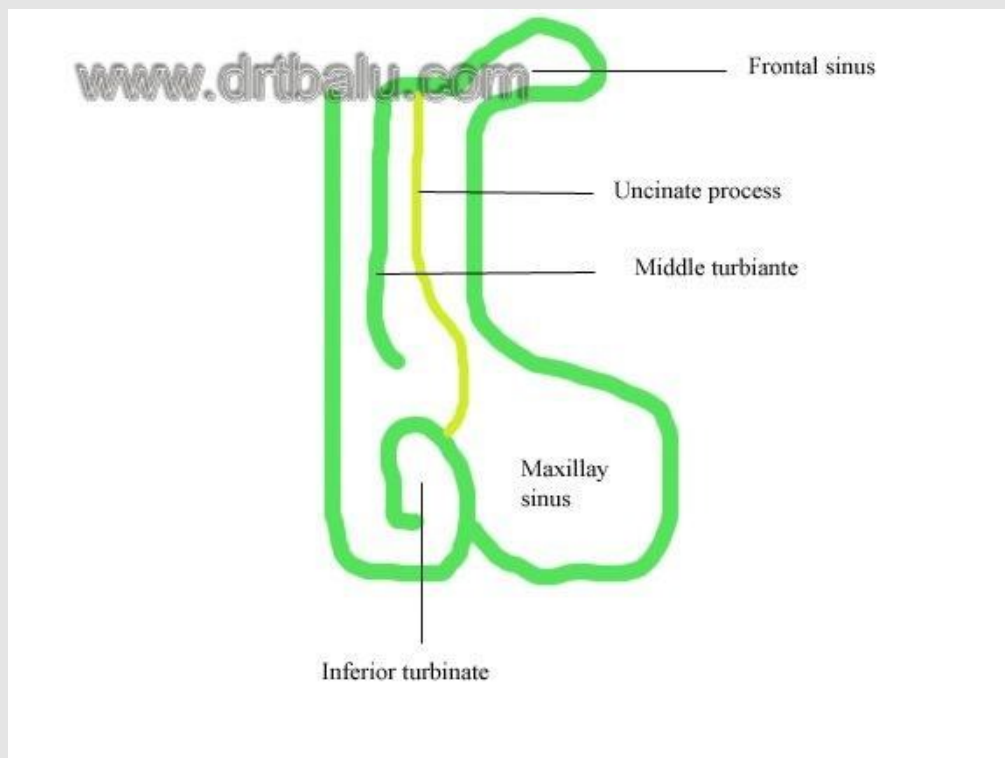
Figure showing Type II uncinate
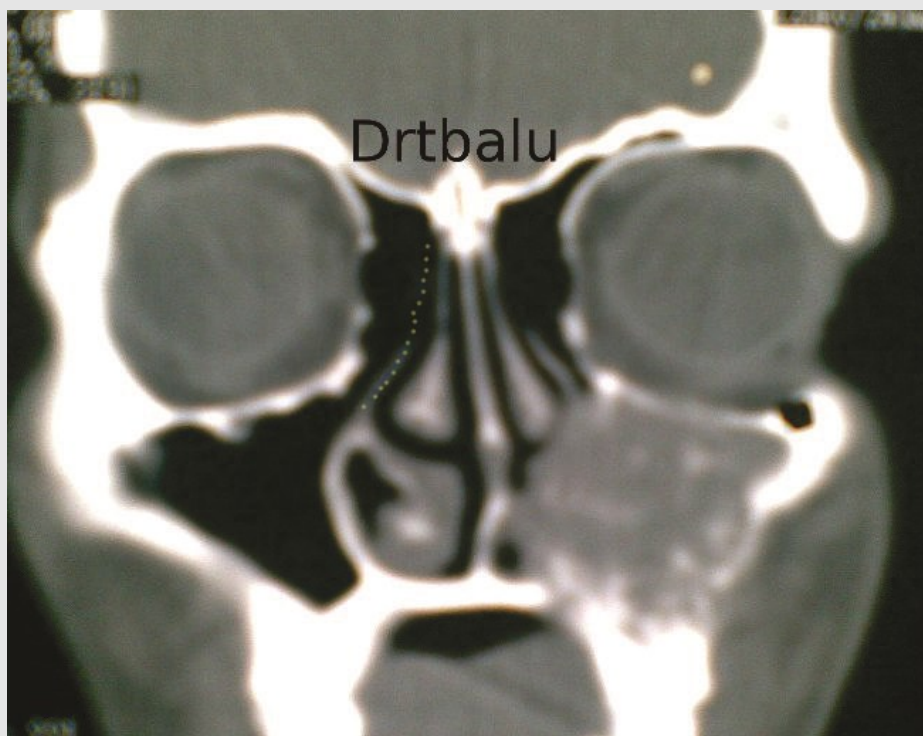
Coronal CT paranasal sinuses showing Type II uncinate

Type III uncinate process:

In this type the superior end of the uncinate process turns medially to get attached to the middle turbinate. Here also the frontal sinus drains directly into the ethmoidal infundibulum.

Uncinate process should be removed in all endoscopic sinus surgical procedures in order to open up the middle meatus. In fact this is the first step in endoscopic sinus surgery.

Rarely the uncinate process itself may be heavily pneumatised causing obstruction to the infundibulum.
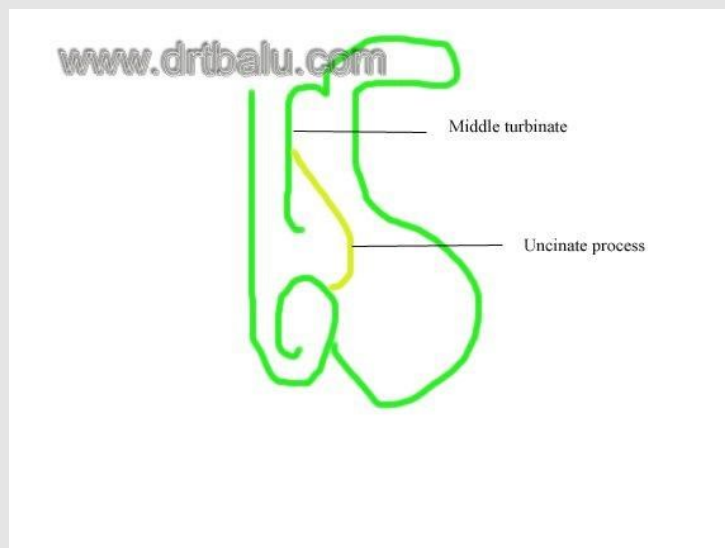
Figure showing Type III uncinate process

Coronal CT showing Type III uncinate

Pneumatized Uncinate process:

Uncinate process can be pneumatized causing narrowing of Osteomeatal complex.
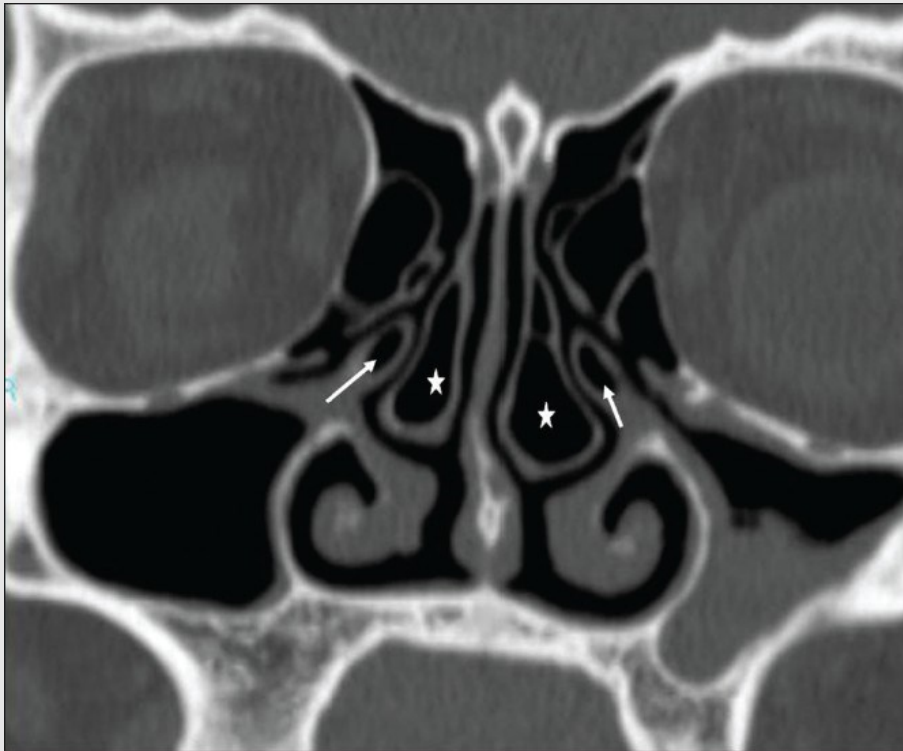
Coronal CT of nose and sinuses showing pneumatized uncinate process (white arrows) and pneumatized middle turbinate (*)

The exact mechanism of uncinate pneumatization is not known. It could be due to growth of agger nasi cells [12] into the most anterosuperior region of uncinate process.

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3. http://www.drtbalu.co.in/dns.html

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5. Wexler D, Braverman I, Amar M. Histology of nasal septal swell body (septal turbinate). Otolaryngol Head Neck Surg 2006;134: 596-600.

6. Zhang L, Han D, Ge W, Xian J, Zhou B, Fan E, et al. Anatomical and computed tomographic analysis of the interaction between the uncinate process and the agger nasi cell. Acta Otolaryngol 2006;126:845-52.

7. http://jorl.net/index.php/jorl/article/view/44

8. Yousem DM. Imaging of sinonasal inflammatory disease. Radiology. 1993;188 (2): 303-14. Radiology (abstract) [pubmed citation]

9. Anatomic relevance of Haller cells in sinusitis Stackpole SA American J of Rhinology 1997 May- jun

10. Polavaram R, Devaiah AK, Sakai O et al (2004) Anatomic variants and pearls-functional endoscopic sinus surgery. Otolaryngol Clin North Am 37 (2):221–42.

11. https://sites.google.com/site/drtbalusotolaryngology/rhinology/uncinate-process

12. Bolger WE, Butzin CA, Parsons DS. Paranasal sinus bony anatomic variations and mucosal abnormalities: CT analysis for endoscopic sinus surgery. Laryngoscope 1991; 101:56-64.

Osteomeatal complex

Ostiomeatal complex [1]: This term is used by the surgeon to indicate the area bounded by the middle turbinate medially, the lamina papyracea laterally, and the basal lamella superiorly and posteriorly. The inferior and anterior borders of the osteomeatal complex are open. The contents of this space are the aggernasi, nasofrontal recess (frontal recess), infundibulum, bulla ethmoidalis and the anterior group of ethmoidal air cells.

This is in fact a narrow anatomical region consisting of :

1. Multiple bony structures (Middle turbinate, uncinate process, Bulla ethmoidalis)

2. Air spaces (Frontal recess, ethmoidal infundibulum, middle meatus)

3. Ostia of anterior ethmoidal, maxillary and frontal sinuses.

In this area, the mucosal surfaces are very close, sometimes even in contact causing secretions to accumulate. The cilia by their sweeping movements pushes the nasal secretions. If the mucosa lining this area becomes inflamed and swollen the mucociliary clearance is inhibited, eventually blocking the sinuses.

Some authors divide this osteomeatal complex into anterior and posterior. The classic osteomeatal complex described already has been described as the anterior osteomeatal complex, while the space behind the basal lamella containing the posterior ethmoidal cells is referred to as the posterior ethmoidal complex, thus recognising the importance of basal lamella as an anatomical landmark to the posterior ethmoidal system. Hence the anterior and the posterior osteomeatal complex has separate drainage systems. So when the disease is limited to the anterior compartment of the osteomeatal complex, the ethmoid cells can be opened and diseased tissue removed as far as the basal lamella, leaving the basal lamella undisturbed minimising the risk during surgery.

Figure showing components of Osteomeatal complex

Obstruction to this area can predispose to sinusitis.

Solken etal [2] described 5 type of obstruction in Osteomeatal complex area.

1.   Infundibular pattern:

Sinus disease is limited to infundibulum and maxillary sinus; fromtal and eth-moidal sinuses are spared. Secondary to swollen mucosa, polyps, Haller cells.

2.   Osteomeatal unit pattern:

Middle meatus, anterior-middle ethmoidal air cells, maxillary and frontal si-nuses are involved. Secondary to swollen mucosa, polyp, concha bullosa, septal deviation, nasal tumor.

3. Sphenoethmoidal recess pattern: Sphenoid and posterior ethmoid air cells are involved.

4. Sinonasal polyp pattern: Polyps fill nasal cavity and sinuses bilaterally

5. Unclassifiable pattern/sporadic pattern: Secondary to retention cysts, mucoceles, post-op changes

Coronal CT sinuses showing infundibular pattern of OMC obstruction

Osteomeatal unit pattern of obstruction
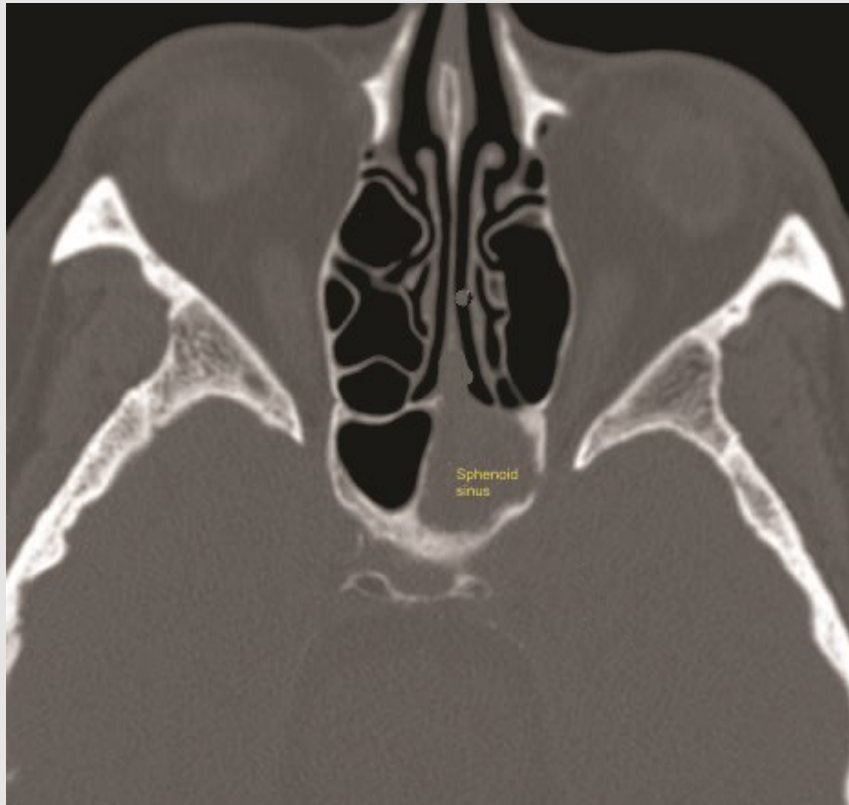
Axial CT of nose and sinuses showing sphenoethmoidal recess pattern of obstruction

Coronal CT nose and sinuses showing sinonasal polypi pattern

Axial CT nose and sinuses showing antral retention cyst

Ethmoidal infundibulum:

This is a cleft like three dimensional space in the lateral wall of the nose. This space actually belongs to the anterior ethmoid. Boundaries of this space include:

Medial wall - Uncinate process and its mucosal covering

Lateral wall - Lamina papyracea of orbit (medial wall of orbit), frontal process of maxilla, rarely lacrimal bone.

Posterior wall - Anterior surface of bulla ethmoidalis

The anterior border of uncinate process fuses with frontal process of maxilla, this causes infundibulum to end blindly anteriorly in an acute angle. This causes infundibulum to appear like a "V" in horizontal sections (i.e. axial CT).

Hiatus semilunaris:

This is a two dimensional space between the anterior wall of ethmoid bulla and the free posterior margin of uncinate process.
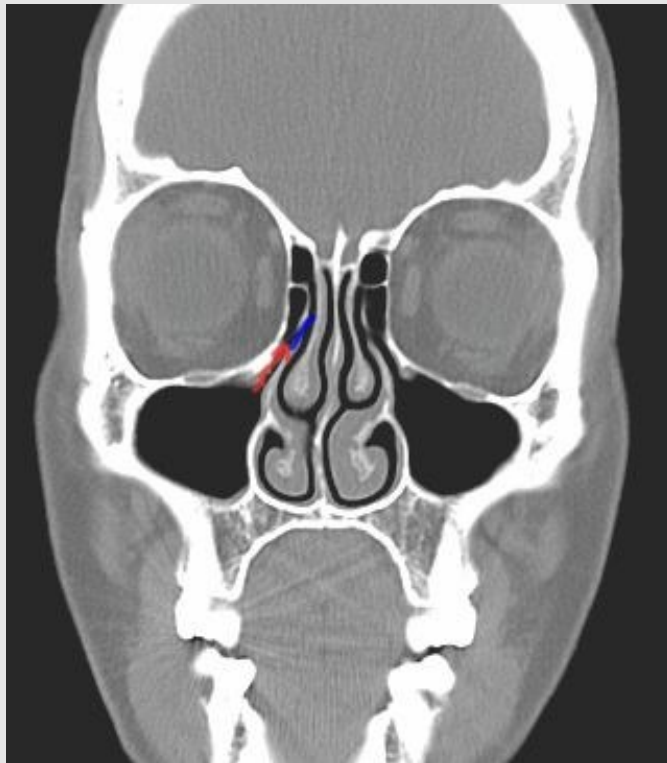
Coronal CT nose and sinuses showing Ethmoidal infundibulum (red line) Hiatus semilu-naris (blue line)

Hiatus semilunaris can be considered as a door through which one can reach the ethmoidal infundibulum.

References:

1. https://sites.google.com/site/drtbalusotolaryngology/rhinology/osteomeatal-complex

2. Eggesbø HB. Radiological imaging of inflammatory lesions in the nasal cavity and paranasal sinuses. Eur Radiol. 2006 Apr;16(4):872-88.

Frontal Sinus

Introduction: Frontal sinus is a complex and highly variable structure. These anatomic variations have a tremendous impact on the direction of drainage, efficiency of mucociliary clearance mechanism and frontal recess morphology. CT scans of frontal sinus have conventionally being performed with continuous 3mm coronal and axial slices. High resolution multiplanar scanners have made sagittal reformatted images a possibility. These scanners enable imaging in three planes.

Embryology: Sinonasal embryology plays an important role in the anatomical variations seen in various patients. Paranasal sinuses begin their development during the first trimester from the six ethmoturbinals. These turbinals enlarge and progressively coalesce to form the lateral nasal wall. The agger nasi cell develops from the most superior remnant of the first ethmoturbinal. The remnant from the descending portion of first ethmoturbinal forms the uncinate process. Basal lamella of the second ethmoturbinal pneumatizes to form Bulla ethmoidalis. The basal lamella of third ethmoturbinal forms the basal lamella of the middle turbinate.

Nasal mucosa invaginates at specific points into the lateral nasal wall forming sinus pits. These sinus pits enlarge to from the maxillary, frontal and ethmoidal sinuses. The mesenchyme around these sinus pits resorbs allowing for enlargement of sinus cavities. The point of mucosal invagination gives rise to the sinus ostium. Frontal sinus drainage pathway is complex because of the variable anatomy of agger nasi, anterior ethmoidal cells, and pattern of insertion of uncinate process.

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The remnant from the descending portion of first ethmoturbinal forms the uncinate process. Basal lamella of the second ethmoturbinal pneumatizes to form Bulla ethmoidalis.

The basal lamella of third ethmoturbinal forms the basal lamella of the middle turbinate.

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Frontal sinus drainage pathway: The frontal sinus grows and expands into the diploic space of frontal bone from the frontal sinus ostium. Each frontal sinus grows independently of the other. Their growth or lack of it is dependent on the ventilation, drainage and growth of surrounding sinuses and skull base.

The frontal sinus narrows inferomedially into a funnel shaped area known as frontal sinus ostium. Anterior wall of this area is bounded by a bony ridge known as "nasal beak". The frontal sinus ostium is oriented perpendicular to the posterior wall of the sinus at the level of anterior skull base.

Some authors divide frontal sinus drainage pathway into superior and inferior compartments. The superior compartment is formed by the union of adjacent air spaces at the antero inferior portion of the ethmoid bone. Its size and shape varies with the variable anatomy of fronto ethmoidal air cells. The superior compartment communicates directly with the inferior compartment. The inferior compartment is a narrow passage way formed by the ethmoidal infundibulum or the middle meatus. If the uncinate process gets attached to the skull base the inferior portion is formed by the ethmoidal infundibulum. On the contrary if the uncinate process gets attached to the lamina papyracea the inferior compartment is formed by the middle meatus.

Frontal recess area: Is anatomically defined as the most anterior and superior part of anterior ethmoidal complex. This is precisely where from the frontal bone gets pneumatized. In the sagittal plane the frontal recess appears like an inverted funnel.

In the sagittal plane the frontal recess appears like an inverted funnel. It opens superiorly into the frontal sinus ostium. The lateral wall of frontal recess area is formed by lamina papyracea. Its medial wall is formed by the vertical attachment of middle turbinate.

Its posterior wall is highly variable, and is formed by the bulla ethmoidalis if it reaches up to the level of skull base. A large bulla could cause narrowing of this critical area obstructing frontal sinus drainage channel. Any imaging modality should critically examine this area where pathology could lurk. The agger nasi cells and the uncinate process play a role in the formation of the floor of this area.
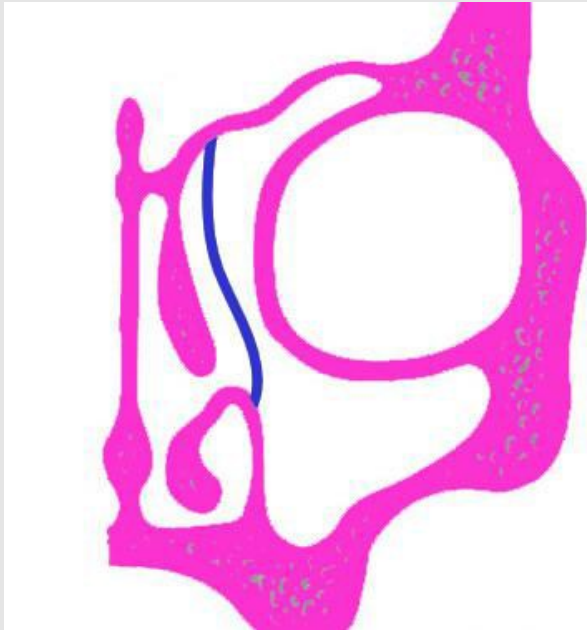
If the uncinate process is attached to skull base as shown in the figure above the frontal recess drains into the superior end of ethmoidal infundibulum.
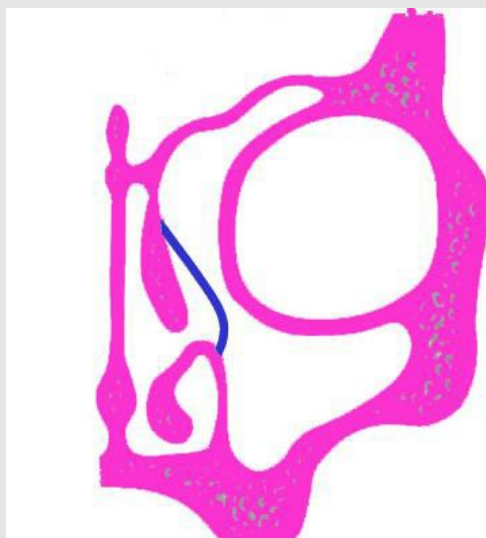
If the uncinate process gets attached to the superior-anterior portion of the middle turbinate as shown in the figure above the frontal recess drains

into the superior end of ethmoidal infundibulum.
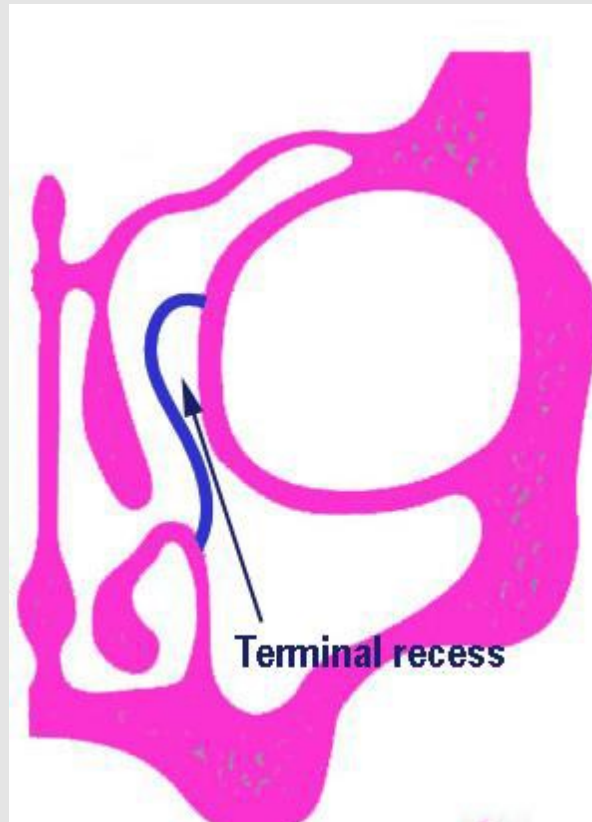
Figure showing terminal recess

If the uncinate process gets attached to lamina papyracea the frontal recess opens directly into the superior aspect of middle meatus. The ethmoidal infundibulum ends directly into a terminal recess.

Frontal sinus drainage can occur via ethmoidal infundibulum if the uncinate process doesn't get attached to the lamina papyracea.
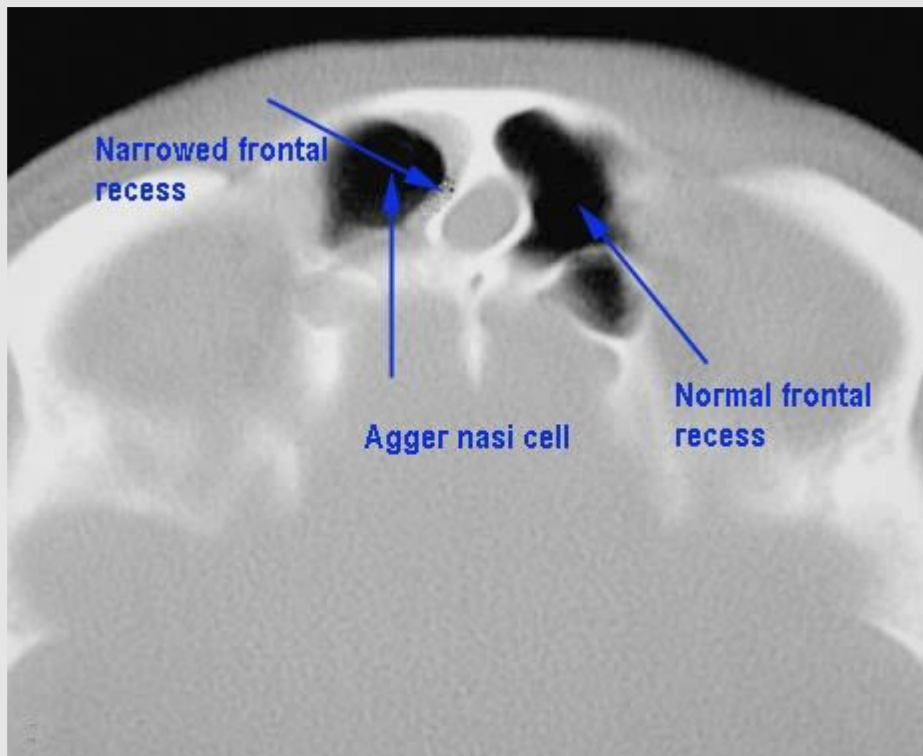
Axial CT showing large agger nasi cell narrowing the frontal recess area obstructing frontal drainage tract
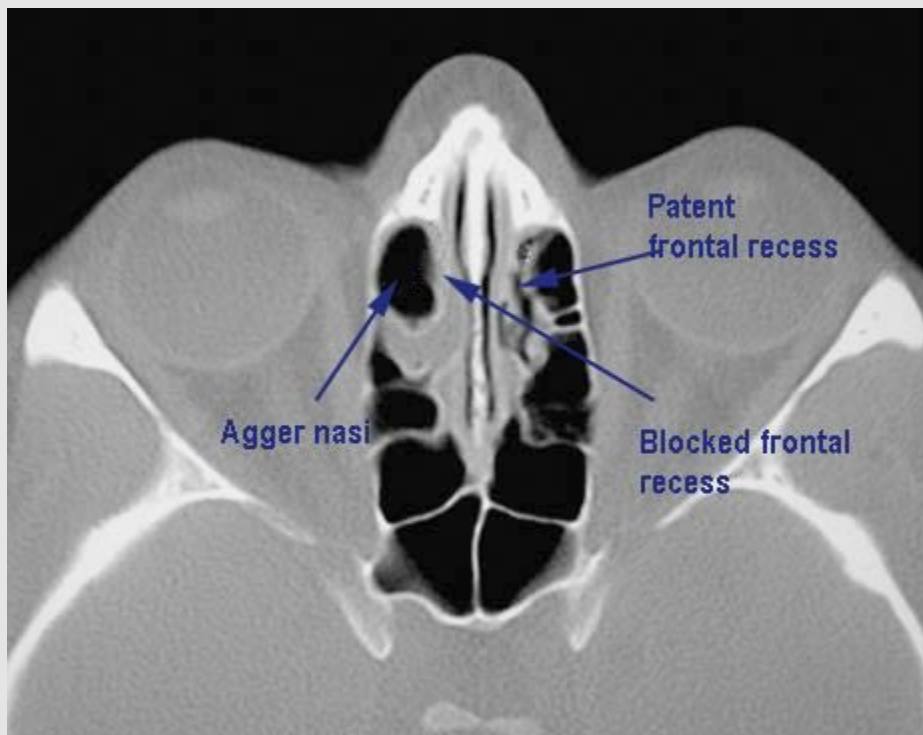
Next axial cut showing enlarged agger nasi cell obstructing the frontal recess area
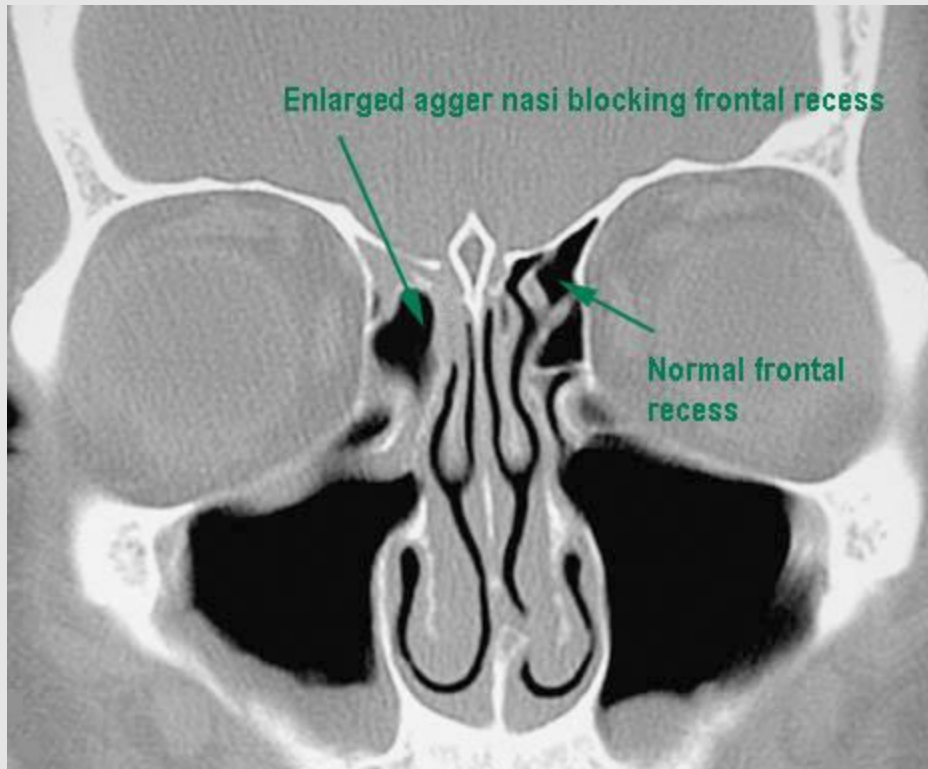
Coronal CT showing enlarged agger nasi blocking frontal outflow tract

CT showing uncinate process attached to skull base. The frontal recess is seen between the agger nasi and uncinate process
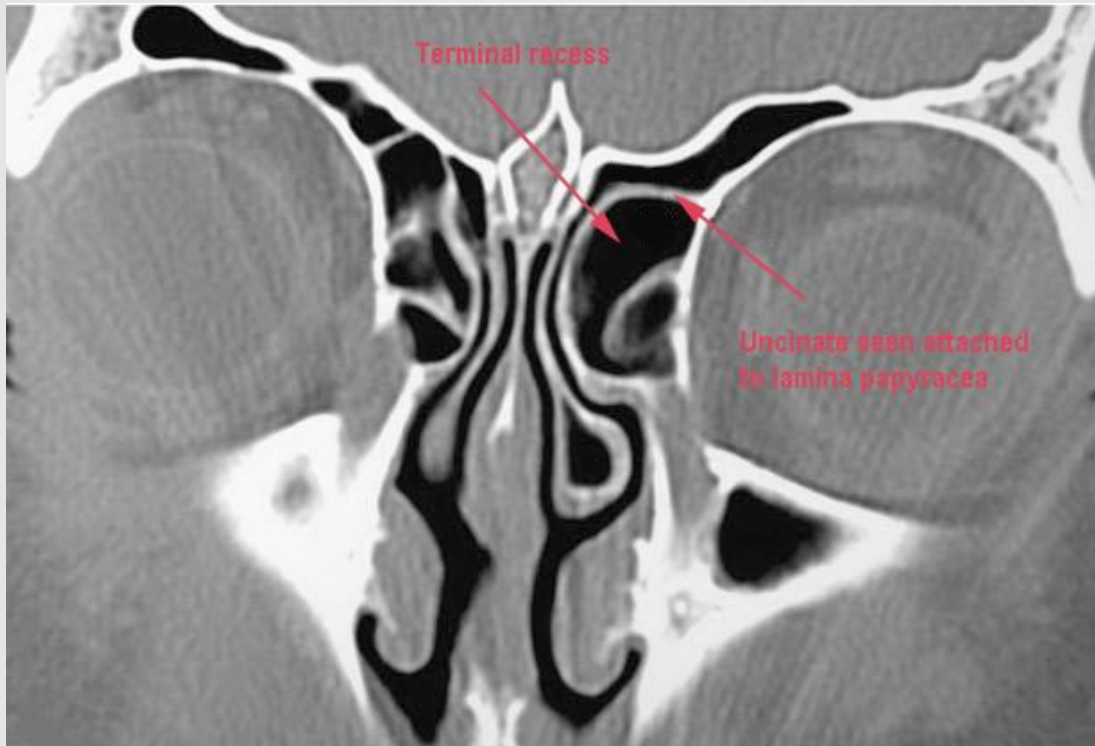
Coronal CT scan showing uncinate process being attached to lamina papyracea. This causes terminal recess to form. Frontal sinus drains directly into middle meatus

as shown in this figure
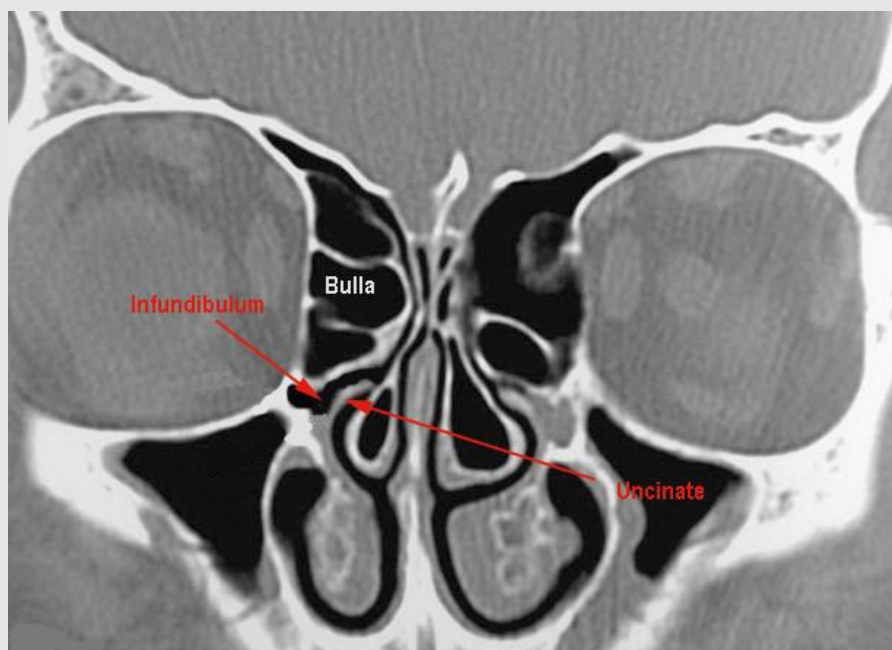
This coronal CT scan shows the uncinate process being attached to the middle turbinate. Note the presence of infundibulum between the bulla and the uncinate process. Frontal sinus is seen opening into the infundibulum. Note also the fairly deep olfactory fossa.

Anatomic variants of frontal sinuses:

Detailed understanding of variations seen in the anatomy of frontal sinus will help the surgeon to avoid unnecessary complications during surgical procedures involving the frontal sinus and skull base.

Frontal cells: These are rare anatomic variants that involve ethmoidal pneumatization that impinge on the frontal recess area. These cells may also extend to involve the lumen of frontal ostium. According to Bent there are four types of frontal cells.

Bent's classification of frontal cells:

Type I frontal cells: This is a single frontal recess cell above the agger nasi.

Type II frontal cells: This is a tier of cells above agger nasi, projecting within the frontal recess

Type III frontal cell: This is a single and massive cell arising above the agger nasi. The pneumatization occurs in a cephalad direction in to the frontal sinus.

Type IV frontal cell: This is a single isolated cell within the frontal sinus. This cell is sometimes difficult to visualize due to its very thin walls.
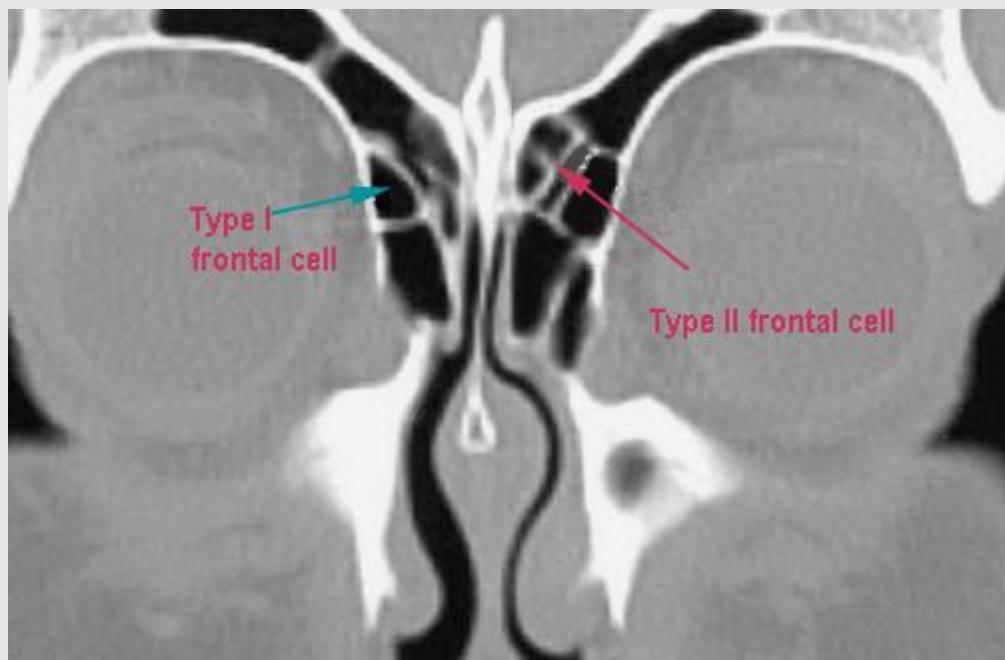
Coronal CT scan showing type I and type II frontal cells

Coronal CT image showing Type III frontal cell

Coronal CT image showing Type IV frontal cell

Supraorbital ethmoidal air cell:

These cells are caused by pneumatization of orbital plate of frontal bone posterior to the frontal recess and lateral to the frontal sinus. Sometimes these supraorbital air cells can reach up to the anterior margin of the orbital plate mimicking a frontal sinus.

Axial CT showing supraorbitalcell

Maxillary sinus

Introduction:

This is the largest of paranasal sinuses. Along with ethmoidal sinus this sinus is present at birth. Maxillary sinus begins its development from the inferior aspect of ethmoidal infundibulum at about 16 weeks [1].

Dimensions of maxillary sinus at birth [2]:

Height - 4mm

Anteroposterior depth - 7 mm

Width - 2.7 mm

Rapid pneumatization of maxillary sinuses continue between ages 1– 8. Initially the floor of the maxillary sinus extends just above the level of the floor of the nasal cavity. Following exfoliation and rep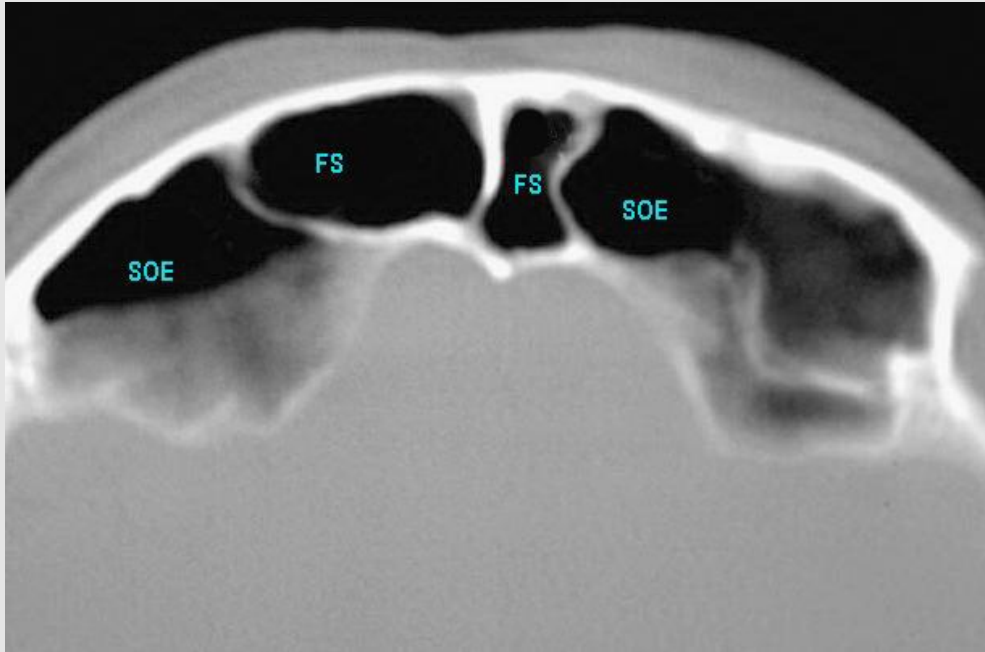lacement of primordial dentition maxillary sinus pneumatization reaches up to the level of floor of the maxillary sinus. In a child the superior wall of maxillary sinus slopes inferolaterally. As the child grows up this slope gradually becomes reduced to form a straight wall.

In adults the maxillary sinus takes the form of pyramid with an interior volume of 15 ml.

Components forming the thin medial wall of maxilla include:

1. Maxilla
2. Inferior turbinate
3. Uncinate process
4. Perpendicular plate of palatine bone
5. Lacrimal bone

Lateral apex of maxillary sinus extends into the zygomatic process of the maxilla. Sometimes it may extend up to the zygomatic bone.

Roof the maxillary sinus is actually the floor of the orbit containing canal for the infraorbital nerve. Sometimes this nerve can be naked bereft of its bony covering. This could be a potential cause for facial pain [3].
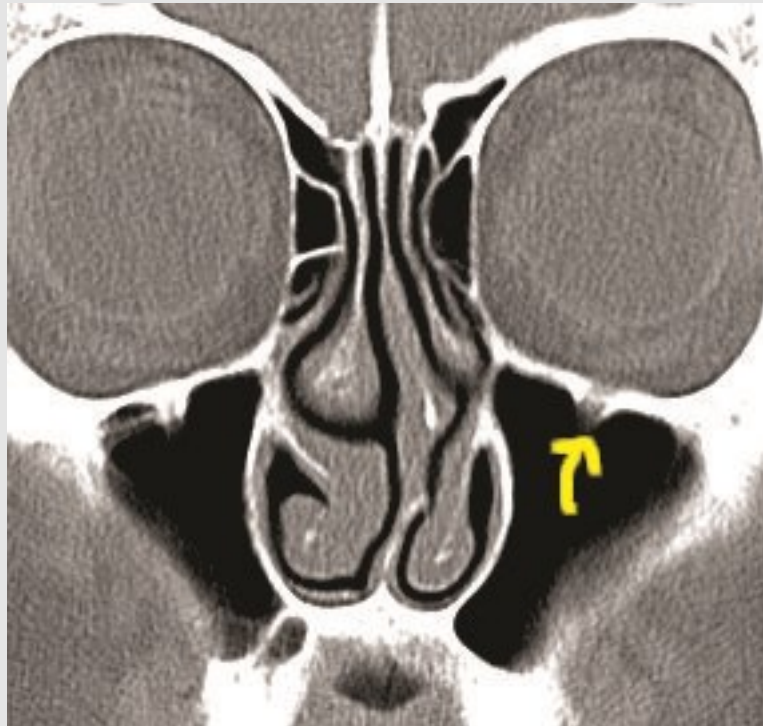
Coronal CT of nose and sinuses showing infraorbital nerve in the roof of maxillary sinus

The floor of maxillary sinus is formed by the palatine process of maxilla. This point actually lies 1 cm below the level of the floor of the nasal cavity. The maxillary sinus is usually separated from molar dentition by a layer of compact bone. Sometimes this layer of bone could be thin or absent providing a direct route of spread of dental infections into the maxillary sinus.

The maxillary sinus classically demonstrates biphasic growth [4]. The first phase of growth occurs during the first 3 years of life while the second growth phase occurs between 7-18 years of age.

The anterior wall of maxillary sinus is thinnest over the canine fossa area. It may just be 2mm thick. Since this portion is the weakest portion of the anterior wall of maxilla this is breached intentionally during Caldwel Luc surgery procedures.

Boundaries of Canine fossa:

Inferior: Bounded by the alveolar ridge

Lateral: Bounded by the canine eminence which is caused by the canine tooth.

Superior: Infra orbital foramen

Medial: Pyriform aperture

Maxillary sinus ostium is placed postero superiorly and hence gravity does not play any role in its drainage. It is only the mucociliary clearance mechanism which clears secretions out of maxillary sinus. Natural ostium may be found at any point along the course of ethmoidal infundibulum. It is more commonly found to open into posterior third of infundibulum [5]. Sometimes accessory ostium could be seen in the medial wall of maxillary sinus. This commonly develops in the posterior fontanel. Widening this accessory ostium does not help in drainage of maxillary sinus because mucociliary clearance mechanism does not allow drainage through accessory ostium.

Natural ostium	Accessory ostium
Present anteriorly not visible under routine direct nasal endoscopic examination	Present posteriorly and can be easily visualized during routing nasal endoscopic examination
Oval in shape	Spherical in shape
Oriented transversely	Oriented anteroposteriorly

Differences between natural and accessory ostium
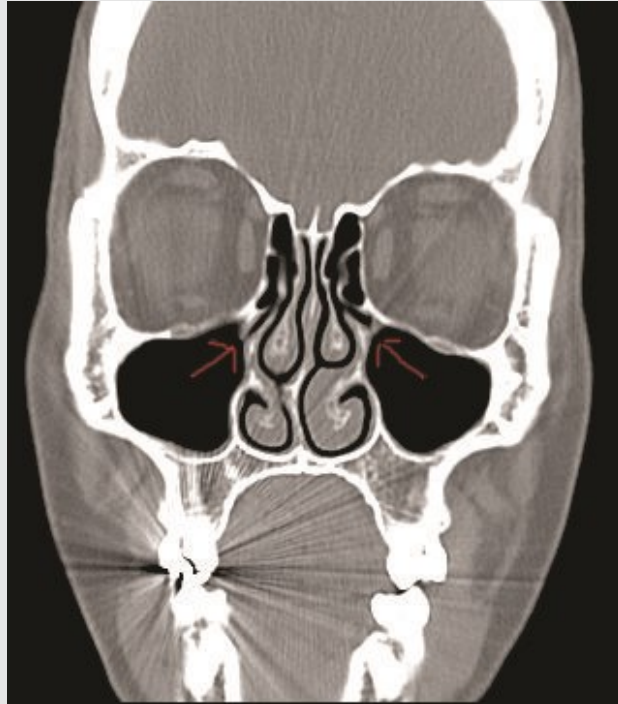
Coronal CT of nose and sinuses showing natural ostium

Coronal CT nose and sinuses showing maxillary sinuses extending much below the level of floor of the nasal cavity
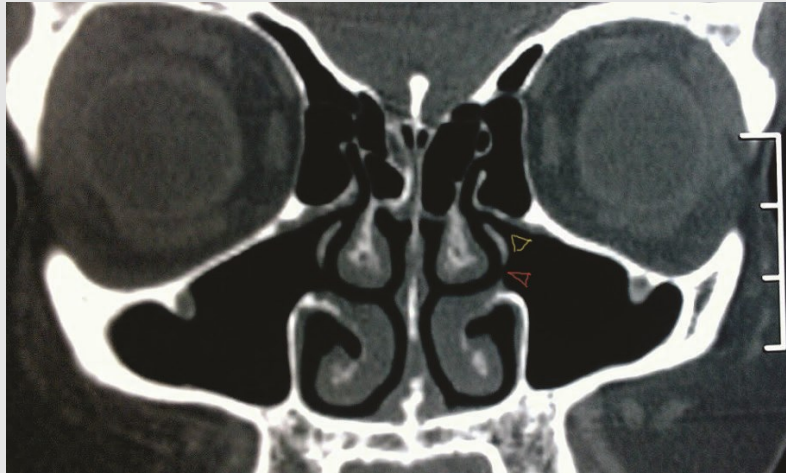
Coronal CT of nose and sinuses showing both accessory (red arrow head) and natural ostia (white arrow head)

Coronal CT image of nose and sinuses showing Hypoplastic maxillary sinuses

Hypoplasia of Maxillary sinuses:

Hypoplasia of maxillary sinus is a rather rare condition. Review of literature reveal that so far only 6 cases have been reported [6].

Incidence of maxillary sinus hypoplasia ranges between (1.5 – 10%).

Majority of these patients reported were asymptomatic and hypoplasia involving maxillary sinuses were identified only on routine radiology. Another study (2002) reports that only about 7 cases of true maxillary sinus hypoplasia have been reported.

Reasons for maxillary sinus hypoplasia:

Hall's Hypothesis [7]:

Hall proposed that intrauterine developmental anomalies to be the cause for hypoplastic maxillary sinus.

Wasson's Hypothesis [8]: According to Wasson sinus infections during the first year of life could cause maxillary sinus hypoplasia.

Bolger's classification[9] of maxillary sinus hypoplasia:

Bolger was the first to associate hypoplasia / aplasia of uncinate process with hypoplasia of maxillary sinus. He considered ethmoid and maxillary sinuses to be intimately related Embryologically. He suggested that developmental abnormalities involving uncinate process will lead to hypoplasia of maxillary sinus also. He classified hypoplasia of maxillary sinuses into three types.

Type I: Mild sinus hypoplasia. Normally developed uncinate process, well developed infundibulum with varying degrees of sinus mucosal thickening,

Type II: Significant maxillary sinus hypoplasia, hypoplastic / absent uncinate process, poorly defined or absent infundibulum, total opacification of affected sinus.

Type III: Profound hypoplasia of maxillary sinus, absent uncinate process

Bassiouny et al 's [10] Classification of maxillary sinus hypoplasia:

They classified maxillary sinus hypoplasia into developmental and acquired categories.

Developmental categories:

1. Isolated hypoplasia due to developmental arrest due to infection / irradiation / injury

2. Developmental anamolies like facial dysostosis

Acquired categories:

1. Trauma with deformity due to fracture of facial skeleton / surgery

2. Inflammatory osteitis (Wegener's granuloma)

3. Hypoplasia due to Thalassaemia / Cretinism

4. Neoplastic osteitis

The fact that there are a number of theories attempting to explain this condition itself suggests that the last word is not yet out on this.

Criteria for diagnosis of maxillary sinus hypoplasia:

Geraghty [11] and Dolan 's diagnostic criteria for diagnosing hypoplasia of maxillary sinus:

1. Enlargement of vertical orbital dimension

2. Lateral position of infraorbital neurovascular canal

3. Elevated canine fossa

4. Enlargement of superior orbital fissure

5. Enlargement of pterygopalatine fissure
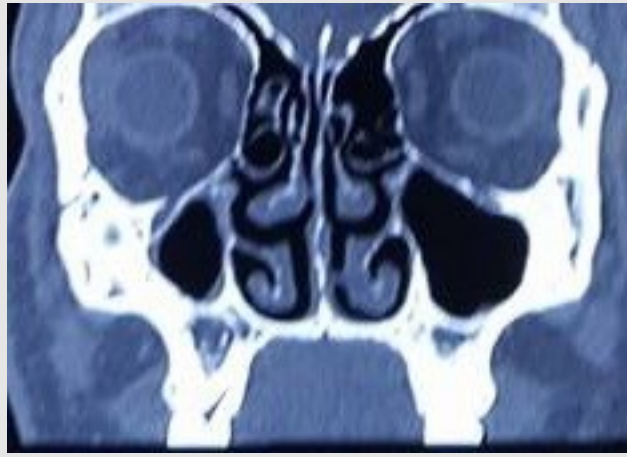
Coronal CT of nose and sinuses showing hypoplasia of right maxillary sinus

Coronal CT of nose and sinuses showing right maxillary sinus hypoplasia. Not the extreme lateral attachment of middle turbinate.

Coronal CT of nose and sinuses showing hypoplasia of right maxilla. Note the opacity of Hypoplastic sinus. This could lead to an erroneous diagnosis of maxillary sinusitis
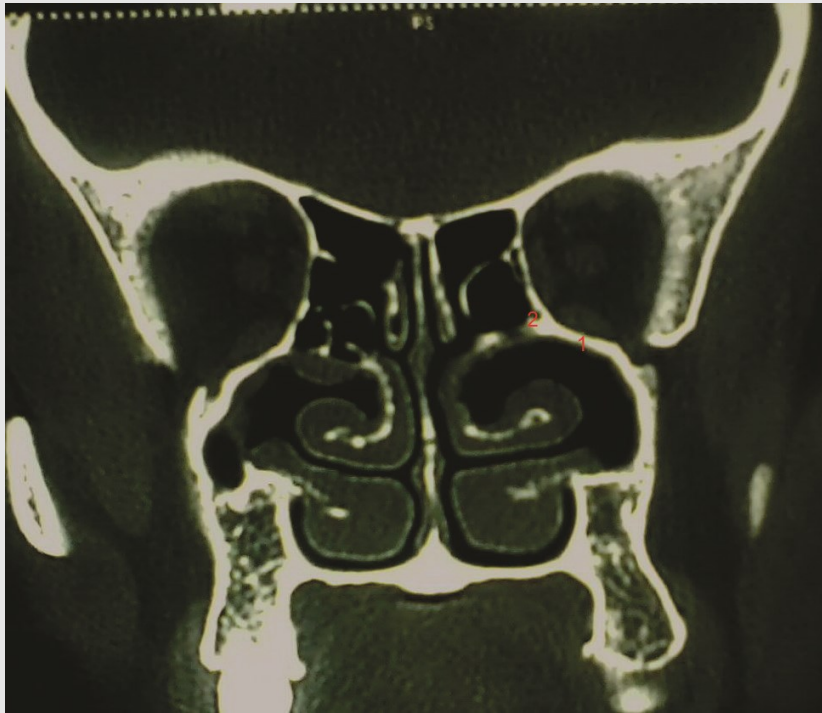
Coronal CT of nose and sinuses showing hypoplasia of both maxillary sinuses. Note the thickened infraorbital margin (1) Attachment of middle turbinate to a thickened lamina papyracea (2) and Hammock skull base

Surgical importance of maxillary sinus hypoplasia:

1. Erroneous diagnosis of sinusitis leading on to unnecessary surgical procedures
2. FESS surgery induced complications because of the difficulty in identifying natural ostium
3. Thickened wall of the sinuses cause problems with antrostomy
4. Very difficult to identify the canine fossa area during antrostomy procedures
5. During surgery CSF leak and skull base injury are common in these patients

Septate Maxillary sinus:

Septations involving maxillary sinuses are rather common. They are asymptomatic [12]. These septations are classified into primary and secondary types.

Primary Maxillary sinus septations:

These septa occur after tooth eruption.

Secondary Maxillary sinus septations:

These septa occur after eduntulation.

Complete or near complete maxillary sinus septa are really rare. Infections involving maxillary sinus is common in the presence of complete or near complete septa of maxillary sinus.

Coronal CT image of nose and sinuses showing septations of maxillary sinus

Sagittal reformatted CT image of nose and sinuses showing septa in the maxillary sinus

Anatomical dissection studies undertaken by Underwood [13] demonstrated that septa involving maxillary sinus is commonly seen in the posterior segment. Anatomical studies showed maxillary sinus septa to be commonly oriented in sagittal or transversal (medial to lateral). CT imaging is the preferred method in identifying this anatomical variation.

Endoscopic view of Septate maxillary sinus

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Sphenoid sinus

Sphenoid sinuses are located at the skull base at the junction of anterior and middle cranial fossae. Pneumatization of sphenoid starts at the age of 3, reaches up to the sella turcia at the age of 7. The entire pneumatization process is completed when the child reaches teen age [1]. The two sphenoid sinuses are asymmetrical separated by intersinus septum. The posterior attachment of intersinus septum is also variable. It may get attached to the bony carotid canal in the lateral wall of sphenoid sinus [2]. Crude attempts to breakdown this septum in such cases can endanger internal carotid artery causing instantaneous death. Intersphenoid septum should be removed to expose the floor of the sella.
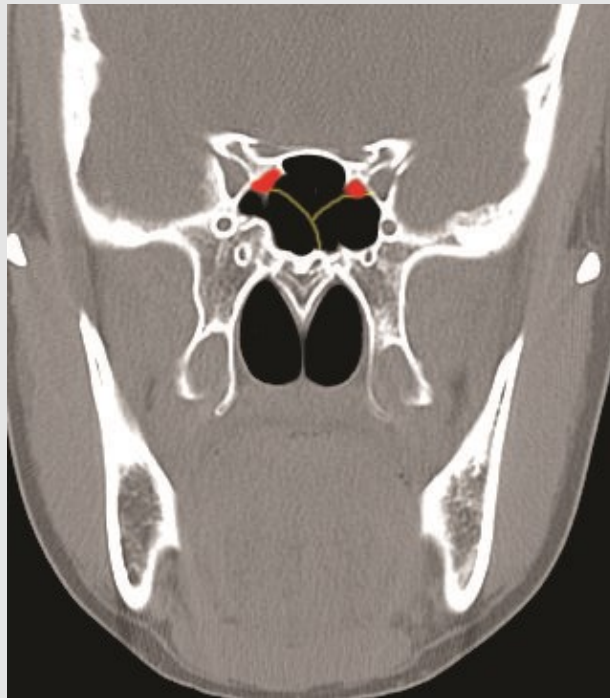
Coronal CT nose and sinuses showing bifurcated sphenoid intersinus septum attached to the bony covering of internal carotid artery

It is safer to use true cut forceps to remove intersphenoid septum. Pneumatization of sphenoid sinus can extend into anterior and posterior clinoid process, posterior portion of nasal septum and vomer.
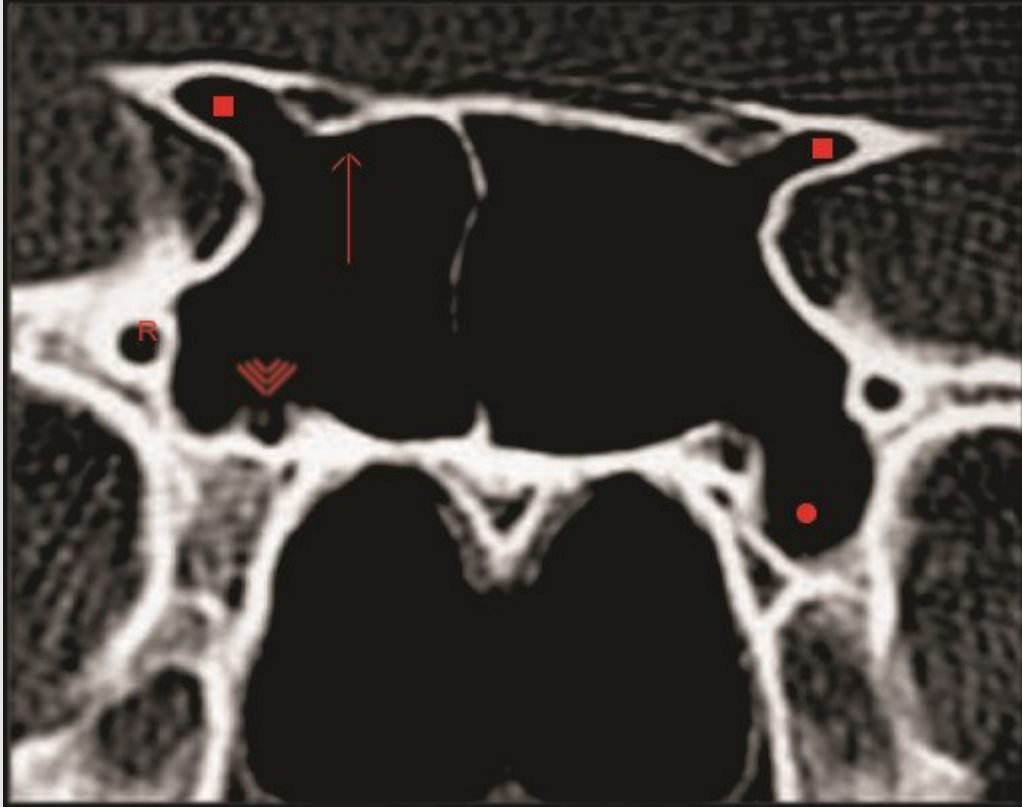
Coronal CT of nose and sinuses. Red square indicates anterior clinoid process pneumatization, Red dot pterygoid pneumatization, Red arrow optic canal, red arrow head prolapsing vidian nerve in the floor of sphenoid sinus. R indicates foramen rotundum.

Coronal CT of nose and sinuses showing pneumatization of posterior nasal septum

Sphenoid sinus drains through a single ostium into the spheno ethmoidal recess. Sphenoid ostium is situated 7 cm from the base of the columella at an angle of 30° with the floor of the nose in a parasagittal plane. This location corresponds to the half way point in the anterior wall of the sinus. The superior turbinate can be used as an useful intranasal landmark during endoscopic sinus surgery. The postero inferior end of superior turbinate points superiorly and medially towards the sphenoid ostium.

Endoscopic view of sphenoid ostium

Superior wall of sphenoid sinus usually represents the floor of sella turcica.

Depending on the extent of pneumatization, the sphenoid sinus can be classified into 3 types:

Conchal: The area below the sella is a solid block of bone without pneumatization.

Presellar: The sphenoid is pneumatized upto the level of the frontal plane of the sella and not beyond

Sellar: This is the most common type of sphenoid pneumatization extending beyond the body of sphenoid, sometimes even up to the clivus.

SPHENOID SINUS

CONCHAL TYPE

SPHENOID SINUS
PRESELLAR TYPE

SPHENOID
SINUS

POST SELLAR TYPE
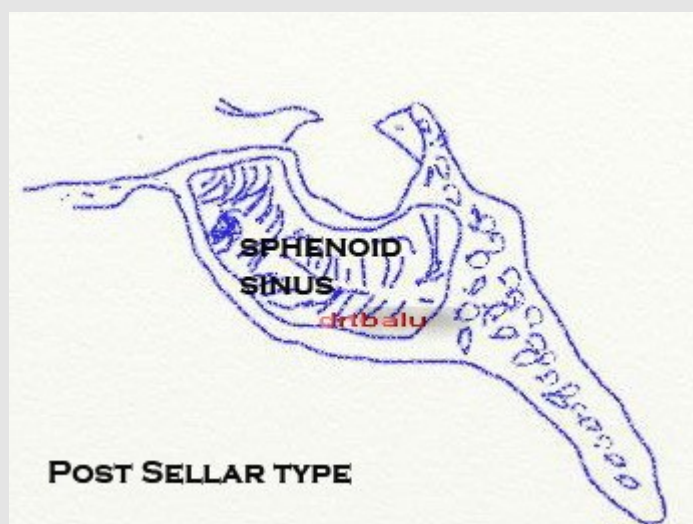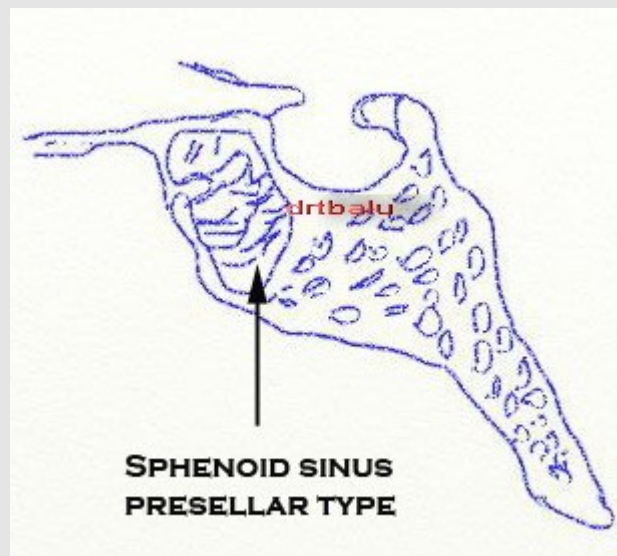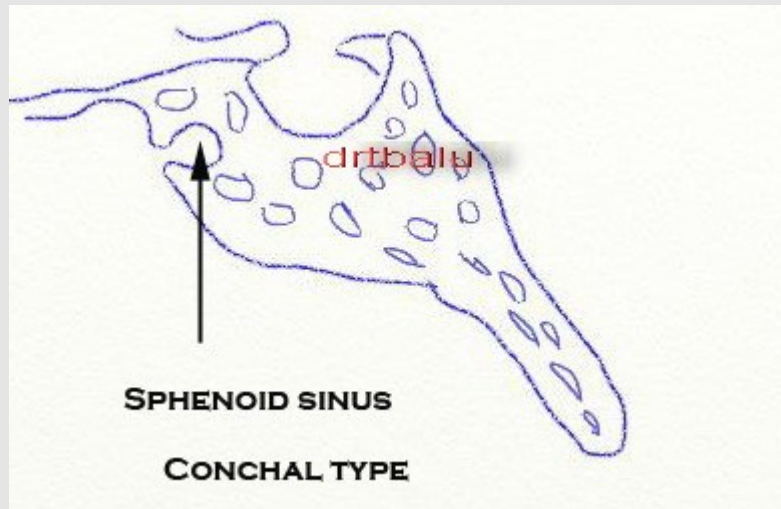
Possible variations of intersinus septum are as follows:

1. A single midline intersinus septum extending on to the anterior wall of sella.

2. Multiple incomplete septae may be seen

3. Accessory septa may be present. These could be seen terminating on to the carotid canal or optic nerve.

Lateral wall of sphenoid sinus: is related to the cavernous sinus. This sinus is formed by splitting of the dura. It extends from the orbital apex to the posterior clinoid process. Cavernous sinus contains very delicate venous channels, cavernous part of internal carotid artery, 3rd, 4th and 6th cranial nerves. It also contains some amount of fatty tissue.

The prominence of internal carotid artery is seen in the postero lateral aspect of the lateral wall of sphenoid sinus. This prominence can be well identified in pneumatized sphenoid bones. On the antero superior aspect of the lateral wall of sphenoid sinus is seen the bulge formed by the underlying optic nerve. These two prominences are separated by a small dimple known as the opticocarotid recess. The optic nerve and internal carotid artery is separated from the sphenoid sinus by a very thin piece of bone. Bone dehiscence is also common in this area.

The roof of the sphenoid (planum sphenoidale) anteriorly is continuous with the roof of ethmoidal sinus. At the junction of the roof and posterior wall of sphenoid, the bone is thickened to form the tuberculum sella. Inferior to the tuberculum sella on the posterior wall is the sella turcica. It forms a bulge in the midline. The bone over the sella could be 0.5 - 1 mm thick. This may get thinner inferiorly. It is hence easy to breech the sella in this thinnest part. This area can be easily identified by a bluish tinge of the dura which is visible through the thin bony covering.
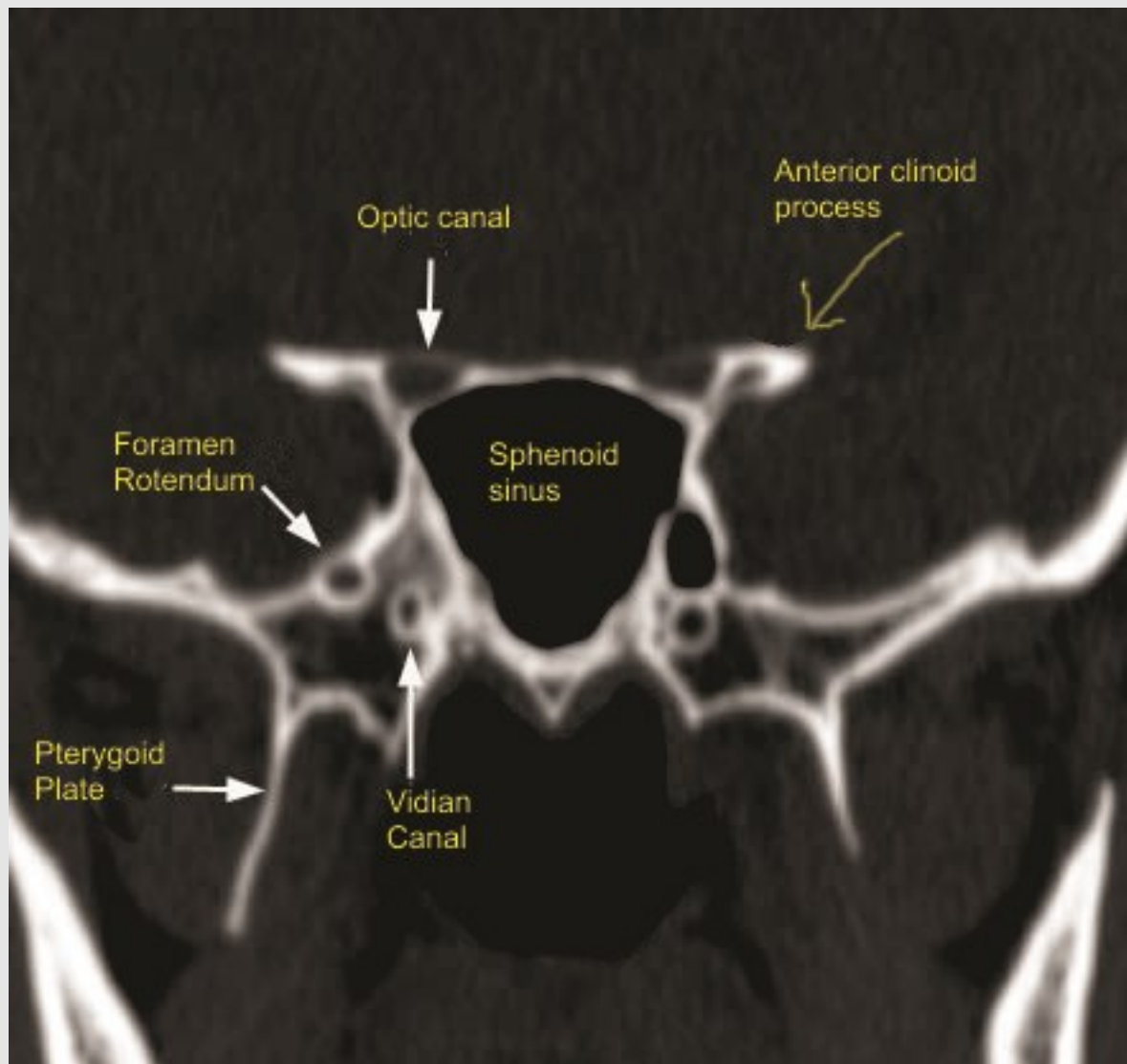
Coronal CT of nose and sinuses showing Sphenoid sinus and its anatomical relations

Currently transphenoid route is considered to be the standard approach to pituitary surgeries [3].

Sphenomaxillary plate:

When there is excessive pneumatization of sphenoid sinus it can abut the maxillary sinus. The separating wall between these two sinuses is known as sphenomaxillary plate [4]. If present this plate lies next to ethmomaxillary plate.

Coronal CT nose and sinuses showing bifurcating sphenoid intersinus septum attaching to optic nerve

Intersinus septum can deviate to one side dividing the sphenoid sinus into unequal portions. Accessory intersinus septa are also commonly seen. They can also be attached to internal carotid artery.

The sella turcica is seen as a prominence in the roof of well pneumatised sphenoid sinus. This bulge is known as the sellar bulge [6]. Sellar bulge is absent in highly pneumatised sphenoid sinus. Hence it is very important to accurately determine the midline when opening the sella. This midline can be confirmed from the base of sphenoid inferiorly or from the remaining anterior sphenoid wall septum attachment superiorly.
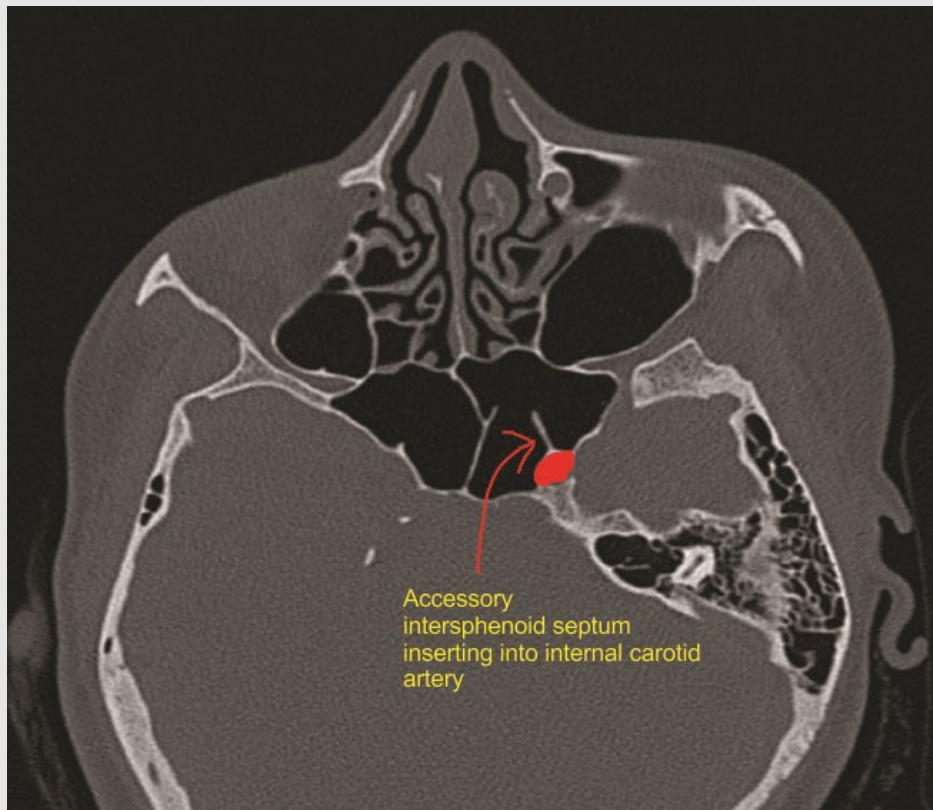
Accessory intersinus septum seen inside sphenoid sinus getting attached to the internal carotid artery.

Highly pneumatised sphenoid sinus can distort anatomy by attenuating the bony wall over the lateral sphenoid wall. This places the optic nerve and internal carotid artery at risk during surgeries involving this area [7].

Optic nerve variations inside sphenoid sinus [8]:

Anatomy of optic nerve within sphenoid sinus is highly variable. Optic nerve relationship with sphenoid sinus can be classified into 4 types:

Type I optic nerve:

In this type the optic nerve courses immediately adjacent to the sphenoid sinus without indenting the wall or contact with the posterior ethmoidal air cells. This is the commonest type seen in nearly 75% of individuals.

Image showing Type I optic nerve

Type II optic nerve:

In this type optic nerve courses adjacent to sphenoid sinus causing an indentation of the sinus wall, but without contact with the posterior ethmoidal air cell.
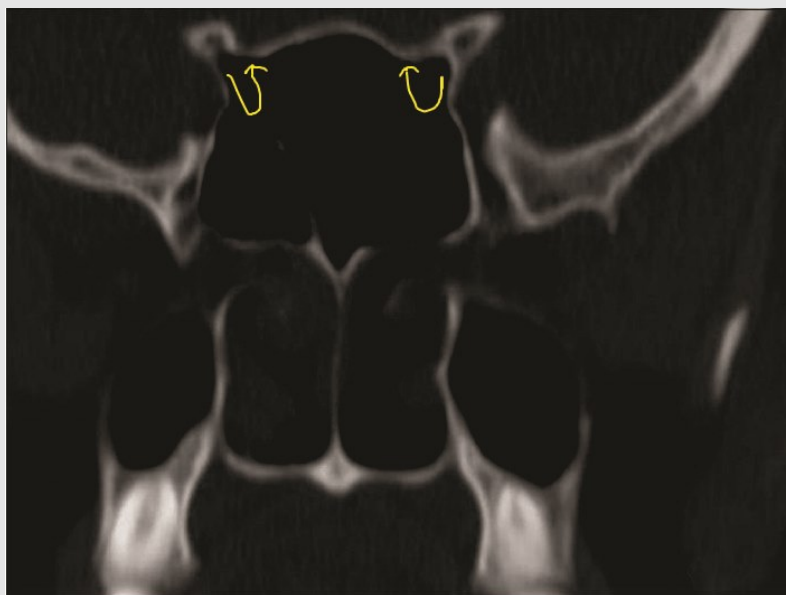
Image showing Type II optic nerve

Type III optic nerve:

In this type the optic nerve courses through the sphenoid sinus, with at least 50% of it being surrounded by air.

CT image showing Type III optic nerve

Type IV optic nerve:

Optic nerve lies immediately adjacent to the sphenoid and posterior ethmoid sinuses.
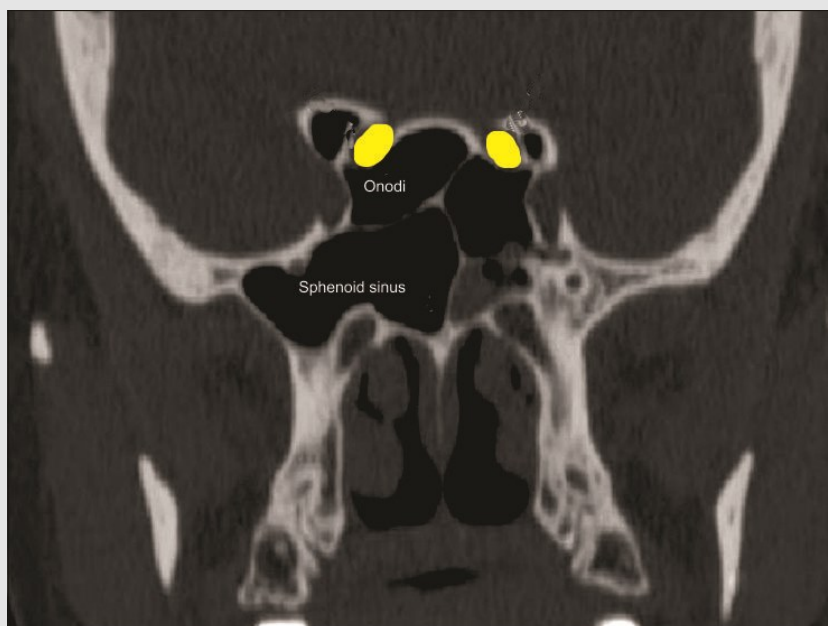
CT image showing Type IV optic nerve
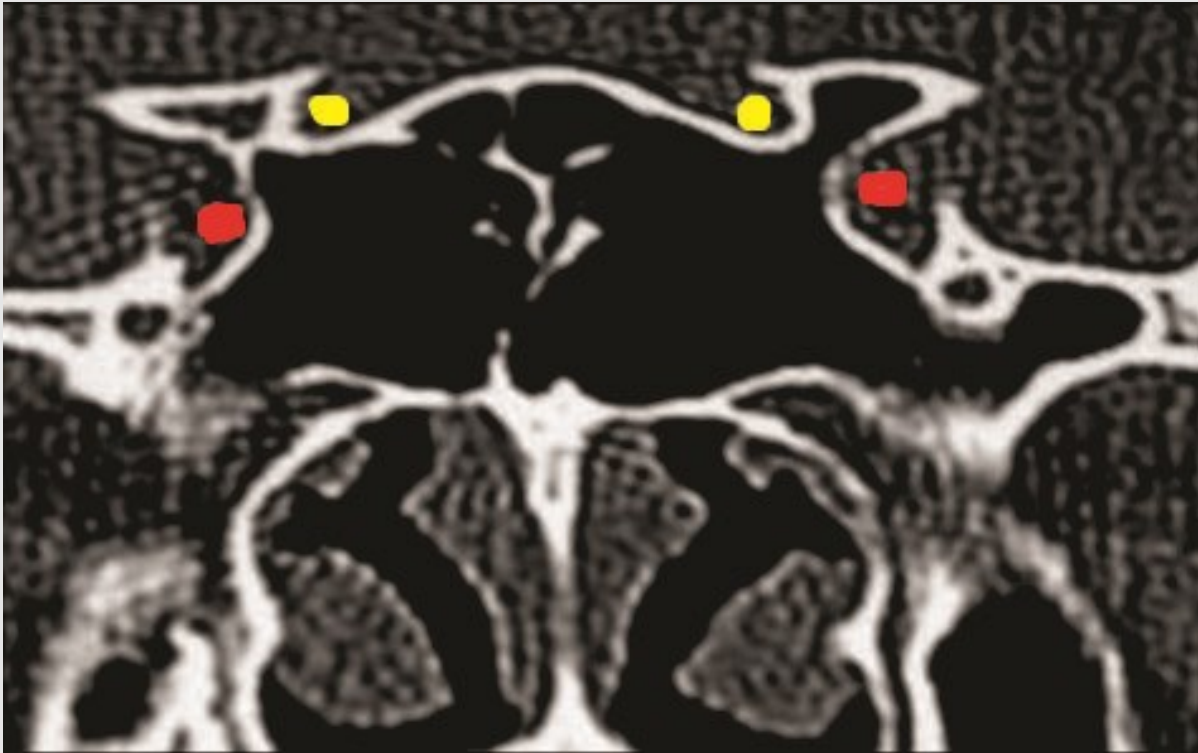
Image showing the relationship between optic nerve and internal carotid artery inside sphenoid sinus

Onodi cell:

This cell belongs to posterior ethmoidal group. This cell also goes by the name Sphenoethmoidal air cell. This cell lies posterior to sphenoid sinus. Very rarely it could lie superior to sphenoid sinus (central onodi air cell). The optic nerve lies very close to this air cell, may be as little as 0.03 mm. Internal carotid artery could also lie close to this air cell. Type IV optic nerve is common in the presence of onodi air cell. Incidence of onodi cell is rather high, one study going to the extent of about 60% [9]. Infections involving onodi air cells puts optic nerve at risk. If surgeon is not aware of this air cell he could cause inadvertent damage to optic nerve during endoscopic sinus surgical procedures.
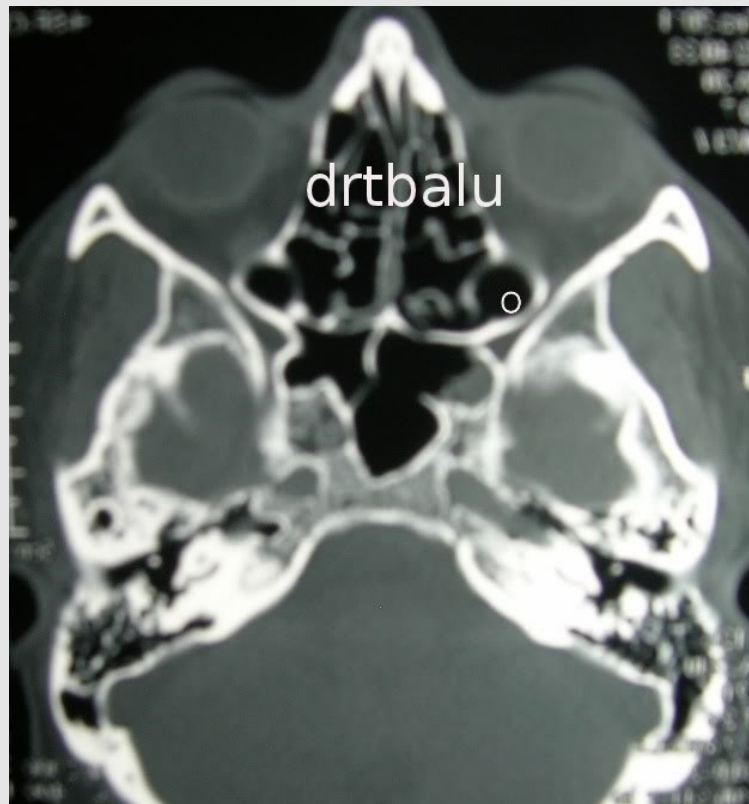
Axial CT image of nose and sinuses showing onodi cell (o)
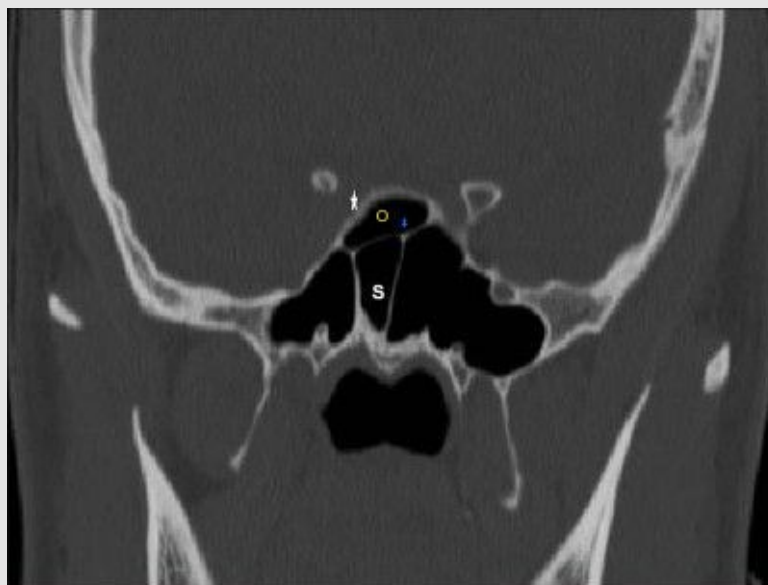
CT Image showing Onodi air cell (S– sphenoid o - Onodi)

Vidian nerve and sphenoid sinus [10]:

The vidian nerve is formed by post synaptic parasympathetic fibers and pre-synaptic sympathetic fibers. This is also known as the "Nerve of pterygoid canal".

Nerves that gets involved in the formation of vidian nerve:

1. Greater petrosal nerve (preganglionic parasympathetic fibers)

2. Deep petrosal nerve (post ganglionic sympathetic fibers)

3. Ascending sphenoidal branch from otic ganglion

Vidian nerve is formed at the junction of greater petrosal and deep petrosal nerves. This area is located in the cartilagenous substance which fills the foramen lacerum. From this area it passes forward through the pterygoid canal accompanied by artery of pterygoid canal. It is here the ascending branch from the otic ganglion joins this nerve.

The vidian nerve exits its bony canal in the pterygopalatine fossa where it joins the pterygopalatine ganglion.

Vidian canal:

It is through this canal the vidian nerve passes. This is a short bony tunnel seen close to the floor of sphenoid sinus. This canal transmits the vidian nerve and vidian vessels from the foramen lacerum to the pterygopalatine fossa.

According to CT scan findings the vidian canal is classified into:

Type I: The vidian canal lies completely within the floor of sphenoid sinus

Type II: In this type the vidian canal partially protrudes into the floor of sphenoid sinus

Type III: Here the vidian canal is completely embedded in the body of sphenoid bone
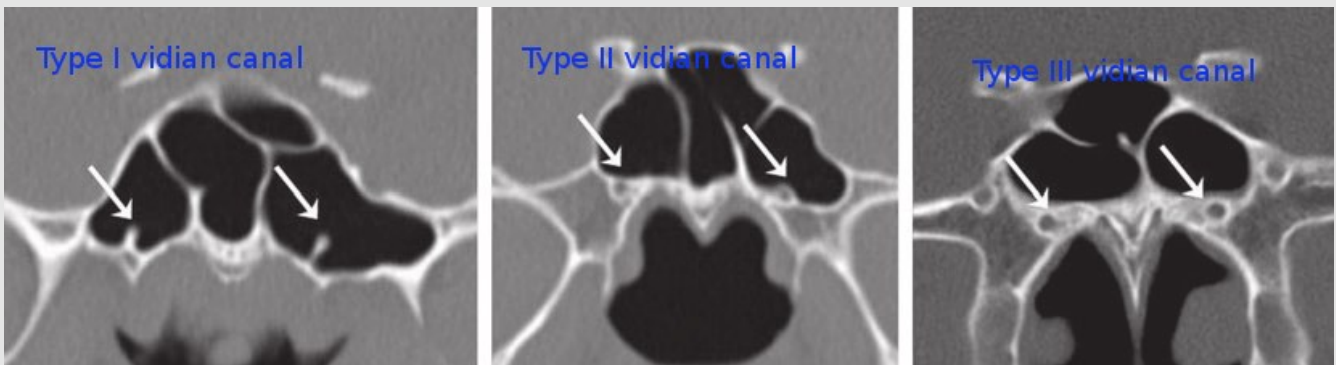
CT image showing the three types of Vidian canal in relation to sphenoid sinus
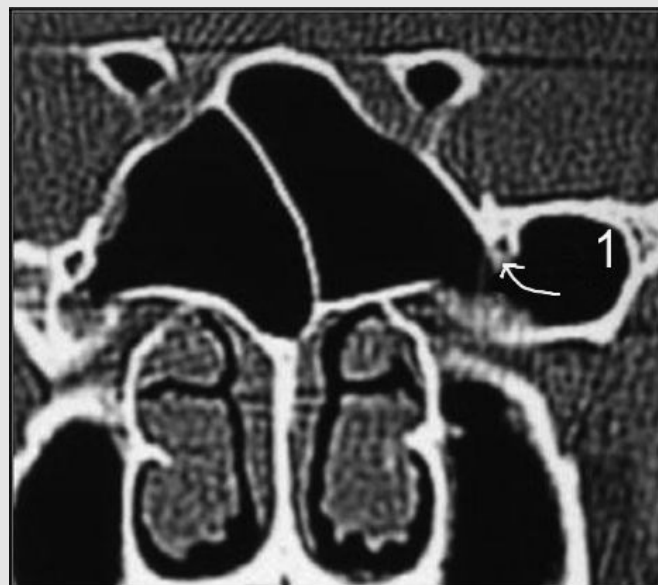
Coronal CT image showing (1) pneumatization of left greater wing of sphenoid. Arrow indicates protrusion of maxillary nerve

The maxillary nerve is found in the maxillary canal (foramen rotundum). This may be dehiscent in some individuals. Pneumatization of greater wing of sphenoid is commonly associated with protrusion of maxillary nerve.

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Inflammatory lesions of nose and sinuses

Introduction:

Mucosal lining of nose and sinuses should be considered as a single entity because they form one continuous lining. Inflammation involving nasal mucosa can also affect the mucosal lining of paranasal sinuses, similarly vice versa is also possible. Hence the term rhinosinusitis would be apt [1]. Inflammation involving mucosa of nose and sinuses could be caused by:

1. Allergic reaction

2. Viral infections

3. Bacterial infections

4. Fungal infections

Sinusitis can also be classified according to the duration of illness:

1. Acute sinusitis - Duration of illness is less than 3 weeks

2. Sub acute sinusitis - Duration of illness ranging between 3-6 weeks

3. Recurrent sinusitis - Recurrent sinusitis with disease free periods in-between attacks.

4. Chronic sinusitis - Duration of illness is more than 6 weeks

Sinusitis can also be classified according to the sinus involved:

1. Frontal sinusitis

2. Ethmoidal sinusitis

3. Maxillary sinusitis

4. Sphenoidal sinusitis

The time frame involved in classification of sinusitis is not absolute. In acute infections mucosa heals without residual effects. In chronic infections there will be some amount of residual effect on the mucosa [2].

Mucosal drainage system of paranasal sinuses are entirely dependent on the mucociliary clearance mechanism. During infections mucociliary clearance mechanism is affected leading on to stasis within the sinus cavity.

Drainage from sinuses has to pass through narrow channels:

1. Frontoethmoidal recess
2. Infundibulum
3. Sphenoethmoidal recess

In anatomical terms these areas are known as tight spots which can easily be obstructed due to mucosal oedema.

Frontal sinus

Frontal cells

Agger nasi

Frontal recess

Nasofrontal beak

Middle meatus

Frontal recess tight spot components

Ethmoidal bulla   Middle meatus

Uncinate process   Hiatus semilunaris

Infundibulum   Retrobulbar recess

Maxillary sinus   Basal lamella

Natural ostium of maxillary sinus

Middle turbinate

Tight spot anatomy in the infundibular area

Superior turbinate   Vidian canal

Posterior ethmoid sinus

Sphenoid sinus ostium

Sphenoid sinus

Optic nerve

Carotid canal

Foramen rotundum

Tight spot anatomy in the sphenoid ethmoidal recess area

These are mucous membrane lined pathways which commonly become obstructed due to mucosal oedema. In acute phases of infections mucosal oedema to these critical drainage area along with temporary disruption of mucociliary clearance mechanism are the major pathophysiologic mechanisms causing sinusitis.

Inflammatory disorders of sinuses can be effectively evaluated by CT imaging of the area. It is not routinely indicated unless there is a suspicion of involvement of areas like orbit and adjacent soft tissue.

Acute sinusitis:

Acute bacterial sinusitis is caused due to bacterial infection in an obstructed sinus [3]. Obstruction of sinus drainage channel is caused due to opposition of contiguous mucosal surfaces due to oedema caused by viral infection. Viral infections involving mucosal lining of nasal cavity is known to predispose to bacterial infection of sinuses. Obstruction to sinus cavity causes changes in the oxygen tension within it predisposing to superadded bacterial infection. Acute sinusitis usually involve a single sinus, ethmoidal sinus being the most commonly involved sinus. These patients have increased risk of intracranial complications with the involvement of frontal, ethmoid and sphenoid [4] sinuses . Orbital complications are also common. Acute viral infections rarely cause acute sinusitis.

Clinically the point of transition from viral sinusitis to acute bacterial sinusitis can be identified when clear secretions formed by viral infections become yellow. Yellowish nasal secretion indicate acute bacterial purulent sinusitis. When inflamed mucosa is imaged (in acute sinus infections) it is seen as enhancing lesion due to the presence of varying amounts of water content in them. Pain occurs in acute sinus infections only when the ostium is blocked and the draining sinus is filled with secretions.
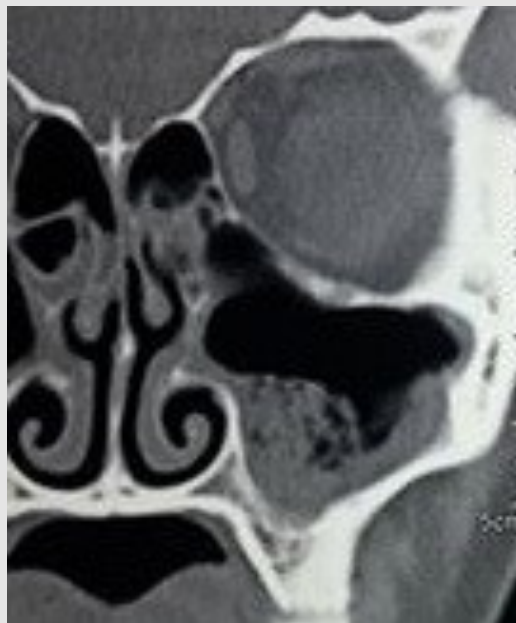
Coronal CT sinuses showing infundibular obstruction with left maxillary acute sinusitis

Coronal CT image of paranasal sinuses showing acute infection involving Haller cell.
Note the fluid level inside the Haller cell cavity

Acute bacterial sinusitis is more likely to spread to orbit than intracranially.
The thin lamina papyracea that separates orbital contents from ethmoidal si-
nuses can easily be breached by infections involving ethmoidal sinuses. In
addition to this the anterior and posterior ethmoidal veins are devoid of
valves allowing spread of infections from ethmoidal sinuses to orbit.
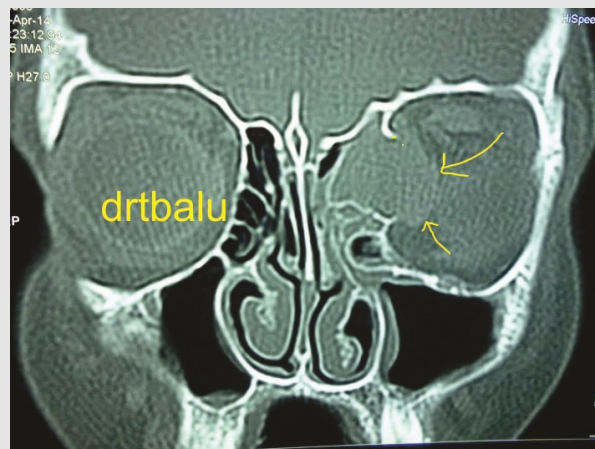
Coronal CT image showing ethmoidal sinusitis involving orbit
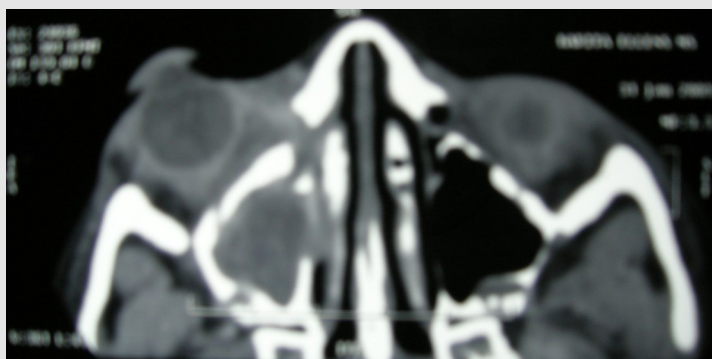
Axial CT showing acute ethmoidal and maxillary sinusitis with orbital cellulitis
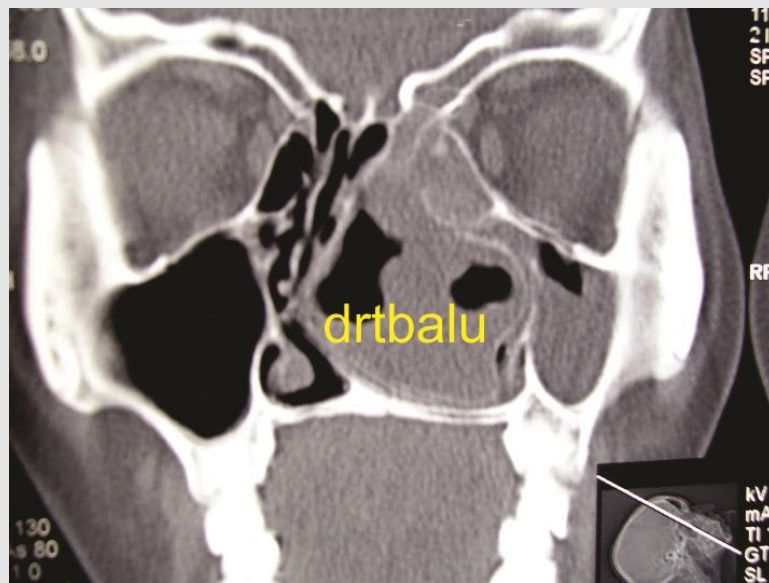
Coronal CT nose and sinuses showing huge infected concha bullosa

Concha bullosa is usually associated with septal deviation to the opposite side. Studies have revealed that septal deviation does not cause concha bullosa, but it augments middle turbinate pneumatization if present [5]. Presence of infection in a huge concha bullosa of middle turbinate also causes secondary maxillary sinusitis on the same side. In this scenario endoscopic resection of lateral wall of concha bullosa would be helpful [6]. Contiguous spread of infection from ethmoid sinus to involve the adjacent lacrimal drainage system causes symptoms similar to that of acute dacryocystitis. Hence before embarking on the management of dacryocystitis it is imperative to perform CT imaging of sinuses. Acute bacterial sinusitis is caused by obstruction to normal drainage channels of sinuses. Hence acute sinusitis occurs as a sinus by sinus event rather than a generalized open.

Even in the presence of pansinusitis due to acute bacterial infections it could be appreciated that one or more of the sinuses are more severely affected than the rest. Asymmetry is the classic feature of acute bacterial sinusitis. In the case of allergic sinusitis there is more or less uniform involvement of all the sinuses as pathophysiology in this condition is more generalized in nature.
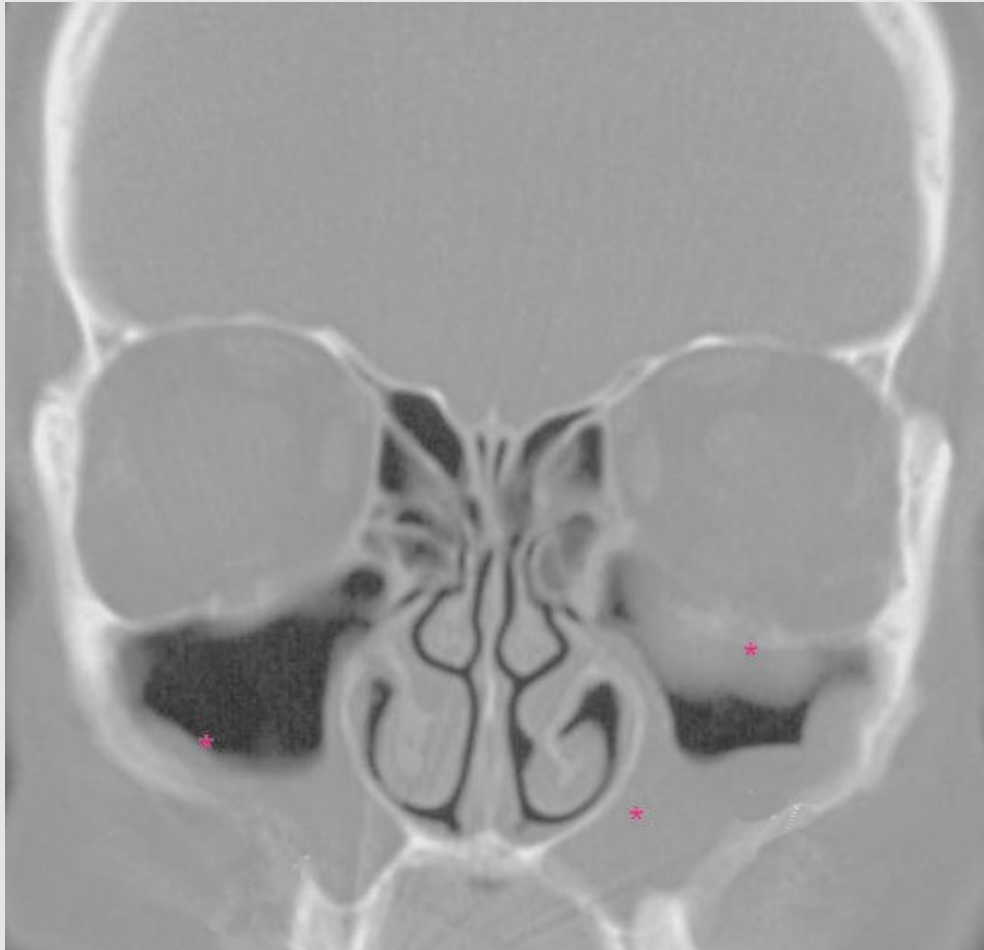
Coronal CT image of nose and sinuses showing evidence of allergic sinusitis. Note the coconut kernel like thickening of maxillary sinus mucosa

Air fluid levels:

Air fluid levels are commonly seen in maxillary sinuses due to acute obstruction of maxillary sinus ostium due to acute bacterial sinusitis. This is commonly seen in about 25% of patients with acute sinus infections. During the era of antral wash, residual fluid level within maxillary sinus could be visualized even up to 4 days following the wash. This has been attributed to the presence of saline used for lavage within the sinus. If patient gives history of antral lavage then CT imaging should be ideally delayed up to a week after lavage. A persistent fluid level even after a week following antral lavage indicates persistent obstruction to sinus drainage.

Image showing axial CT image of nose and sinuses showing fluid level in the maxillary sinus cavity
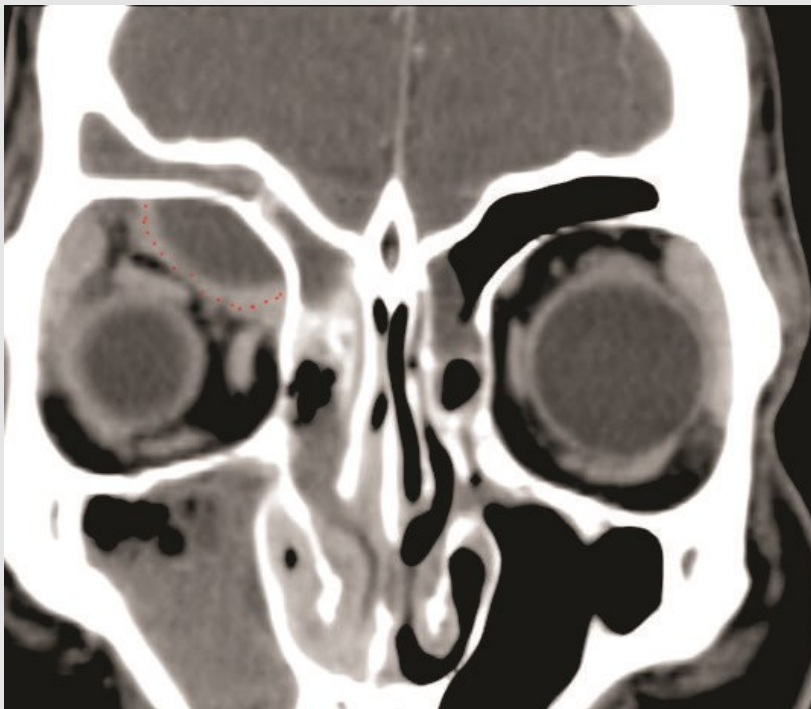
Coronal CT of nose and sinuses showing acute maxillary sinusitis with right orbital sub-periosteal abscess

Nasogastric tube placement and prolonged supine positioning can cause air fluid levels to occur in maxillary sinuses. Naso gastric tube interferes with maxillary sinus discharge due to nasal mucosal oedema. Maxillary sinus drainage block starts within the first 24 hours of insertion of naso gastric tube [7].

Significance of air fluid level varies according to the sinus involved. If air fluid level is present in frontal sinuses it invariably means acute bacterial sinusitis. Intracranial complications occur within 48 hours of frontal sinus infection [8]. If symptoms don't show improvement or if imaging shows evidence of air fluid level even after 48 hours after treatment then trephining of the sinus should be considered.

Air fluid level in ethmoid sinuses is a rare occurrence. Even if present it should be considered as a Mucopyocele due to rupture of ethmoidal muco-cele with partial drainage into the nasal cavity.
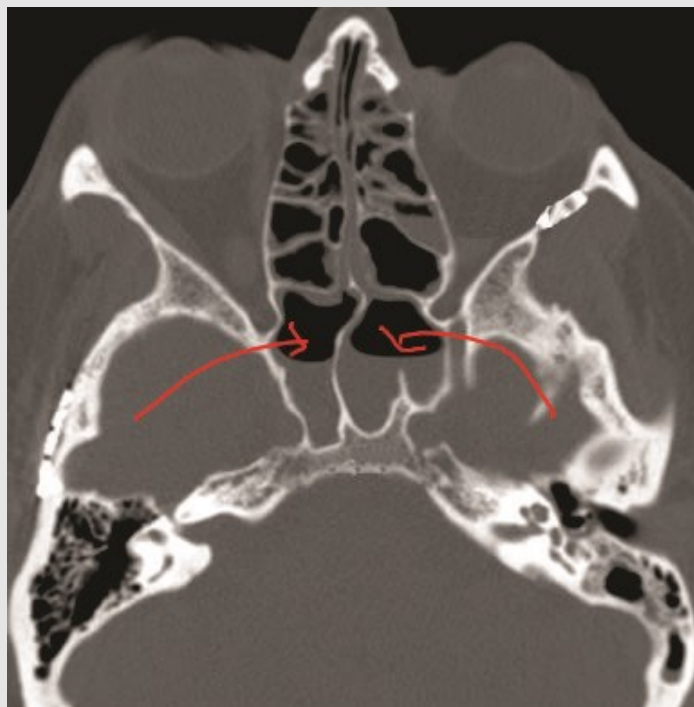
Axial CT of nose and sinuses showing fluid level in ethmoid and sphenoid sinuses

Presence of air fluid level in sphenoid sinus indicates the presence of acute sinusitis / nasal obstruction. In patients with history of head injury, presence of air fluid level in sphenoid sinus indicates presence of hemorrhage / CSF leak.

Chronic sinusitis:

This is a common and more prevalent illness. This term indicates presence of inflammatory process in the mucosal lining of paranasal sinuses for 12 weeks or longer. Chronic sinusitis is always associated with concurrent nasal airway inflammation. Since chronic sinusitis is always preceded by rhinitis the term chronic rhinosinusitis would be more appropriate. Majority of chronic sinusitis are caused by continuation of unresolved acute sinusitis. Sometimes chronic sinusitis can occur in the absence of acute sinusitis.

In 1996 American Academy of Otolaryngology - Head and neck surgery Multidisciplinary Task force came out with adult rhinosinusitis diagnostic criteria which included [9]:

1.   Facial pain

2.   Nasal obstruction

3.   Nasal discharge / Purulence

4.   Hyposmia

5.   Anosmia

6.   Fever

7.

In 2003 this criteria was widened to include radiological evidence also.

Chronic sinusitis may manifest as one of the three following syndromes:

1.   Chronic rhinosinusitis without nasal polypi

2.   Chronic rhinosinusitis with nasal polypi

3.   Allergic fungal sinusitis

This classification is significant because of the varying treatment methodologies followed to treat them.

Pathophysiology of chronic sinusitis:

Stasis of secretions within the sinus cavities triggered by:

1. Mechanical obstruction at the level of Osteomeatal complex due to prevailing anatomical anomalies.

2. Mucosal oedema due to various causes

Current concept:

Currently chronic rhinosinusitis is considered to be a multifactorial disease due to:

1. Persistent infection (Including osteitis and presence of biofilm)

2. Allergy and other immunological disorders

3. Intrinsic factors of upper airway

4. Super antigens

5. Colonizing fungi that induce and sustain eosinophilic inflammation of sinus mucosa

6. Aspirin sensitivity

Coronal CT showing chronic sinusitis with nasal polyposis (Note turbinates cannot be differentiated from nasal polypi unless window setting is changed to bone window)

Coronal CT image of nose and sinuses bone window setting. Here turbinates and polypi can clearly be differentiated

Management of chronic rhinosinusitis should be based on the causative factors which include:

Ostial blockage

Delayed recovery of mucociliary function

Mucous recirculation and presence of associated osteitis

Microbial factors causing persistence of infection

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Mucoceles

Introduction:

Mucoceles are gradually expanding lesion involving paranasal sinuses. This is usually caused due to obstruction to the normal drainage channels of paranasal sinuses leading on to pent up secretions within it. These patients classically don't present with symptoms pertaining to nose and sinuses but with ophthalmological signs and symptoms. They invariably present to the opthalmologist before finding their way to an otolaryngologist.

Definition:

A mucocele is defined as mucous filled epithelium lined sac. Mucoceles commonly involve ethmoidal and frontal sinuses. Mucoceles are commonly caused due to obstruction to drainage channel of paranasal sinuses. These expansile cystic masses are sometimes filled with mucopurulent secretions[1]. Sometimes associated bone destruction is also evident [2].

Mucoceles are rather common in frontal sinuses. Next comes the ethmoidal sinuses. Isolated mucoceles involving ethmoidal sinuses are rather rare [3]. They always occur in combination with frontal / sphenoid mucoceles [4].

Etiopathogenesis:

Mucoceles have been postulated to form due to obstruction of sinus ostia following chronic infections / allergic reactions involving paranasal sinuses [5]. Previous trauma / surgery can also cause obstruction to sinus outflow channels causing formation of mucoceles. Ethmoidal mucoceles if present in isolation could be caused by endoscopic ethmoidectomy [6]. Some studies have reported occurrence of isolated ethmoidal mucoceles even 10 years after surgery. Paranasal sinuses continues to expand slowly owing to pent up mucous secretions. These mucoceles are lined by dilated ciliated columnar epithelium which secrete mucous causing expansion of the cyst. Continuing expansion of this cyst puts pressure on the bony walls of paranasal sinuses, causing bony erosion and remodeling.

Unchecked extension of sinus cavity can cause extension of mucocele into orbit, nasopharynx and cranial cavity [7]. In addition to pressure changes inflammatory mediators like prostaglandins, interleukins and tumor necrosis factor present within mucoceles also contribute to their expansion capability [8].

Three main theories of pathogenesis of mucocele formation has been postulated:

1. Pressure erosion

2. Cystic degeneration of glandular tissue

3. Active bone resorption and regeneration

Sites involved by mucoceles include [9]:

1. Anterior ethmoid

2. Frontal

3. Maxilla

4. Posterior ethmoid

5. Sphenoid

About 60% of paranasal sinus mucoceles are present in the frontoethmoidal region
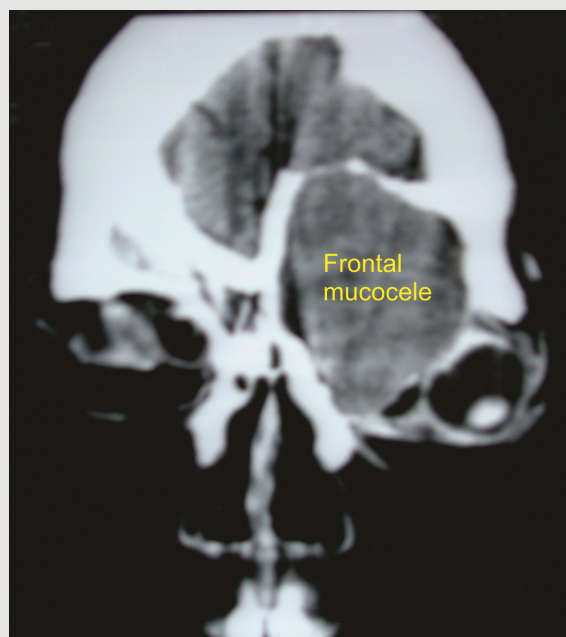
Coronal CT of nose and sinuses showing frontoethmoidal mucocele with intracranial extension

Role of imaging in mucoceles:

Mucoceles are best imaged using a combination of CT and MRI scans. CT scans helps to assess bony changes while MRI scans assess extensions into orbit / cranium with great degree of accuracy.

CT scan features:

1. Complete Opacification of involved sinus [10]

2. Expansion and thinning of involved sinus margins

3. Areas of complete bone resorption with resultant extension into adjacent areas like orbit and cranium

4. Contrast CT shows peripheral enhancement
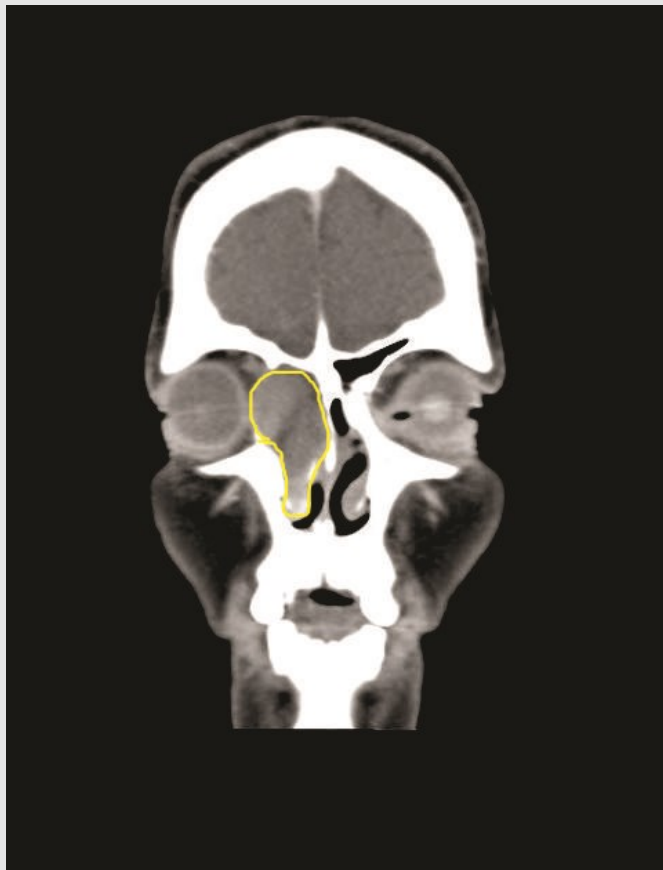
Coronal CT image showing Ethmoid sinus mucocele
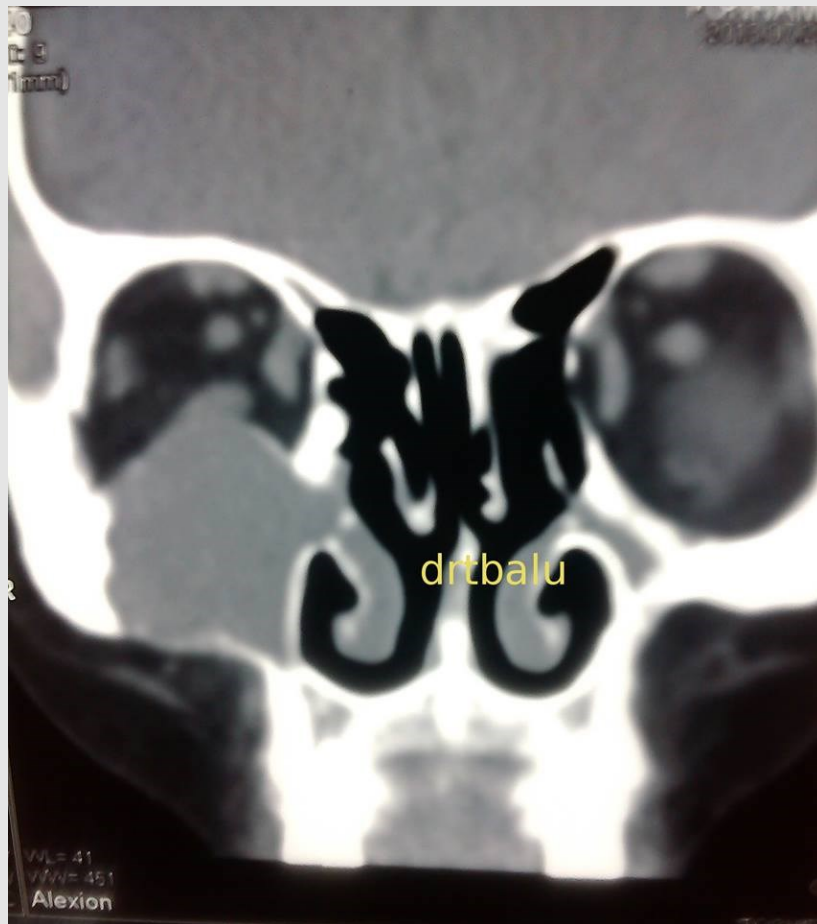
Coronal CT of nose and sinuses showing mucocele involving right maxillary sinus with erosion of inferior orbital wall
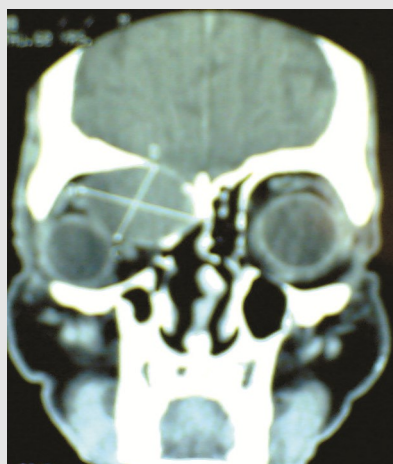
Coronal CT image of nose and sinuses showing frontal mucocele

Axial CT of nose and sinuses showing Sphenoidal mucocele

Note: Sphenoidal mucoceles can present with vision disturbances.

Classification of frontal mucocele:

Frontal mucoceles have been classified into 5 types depending on its extent.

Type I: In this type the mucocele is limited to the frontal sinus only with or without orbital extension.

Type II: Here the mucocele is found involving the frontal and ethmoidal sinuses with or without orbital extension.

Type IIIa: In this type the mucocele erodes the posterior wall of the frontal sinus with minimal or no intracranial involvement.

Type IIIb: In this type the mucocele erodes the posterior wall with major intra cranial extension.

Type IV: In this type the mucocele erodes the anterior wall of the frontal sinus.

Type Va: In this type there is erosion of both anterior and posterior walls of frontal sinus without or minimal intracranial extension.

Type Vb: In this type there is erosion of both anterior and posterior walls of frontal sinus with a major intracranial extension

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Fungal Sinusitis

Introduction:

Fungi are eukaryotic organisms comprising of moulds, yeasts, mushrooms and other similar organisms. Among this group of organisms only about 0.1% are human pathogens. The term mycosis is used to define diseases caused by fungi [1].

Mycosis can be classified under 4 heads based on the portal of entry and site of infection.

Types of Mycosis:

Type	Pathophysiology	Route	Example
Superficial	Limited to keratinized tissues	Topical	T. pedis
Subcutaneous	Localised to subcutaneous tissues	Broken skin	Rhinosporidiosis
Systemic	Disseminated widely	Inhalation	Histoplasmosis
Opportunistic	Local / Disseminated	Cell mediated immunity compromise	Candida / Mucormycosis

Fungal infections of nose and sinuses are getting common these days. With increasing incidence of HIV and other diseases like diabetes which compromise host immunity it is no wonder that the incidence of fungal infections involving nose and para nasal sinuses is on the rise. In India the incidence of fungal sinusitis in immuno competent patients is also showing a rise. This particular fact need to be studied further.

Classification of fungal sinusitis [2]: There are 5 different types of fungal sinusitis with differing pathophysiology and clinical presentation. They include:

1. Acute fulminant invasive sinusitis

2. Chronic invasive fungal sinusitis

3. Granulomatous invasive fungal sinusitis

4. Fungal ball

5. Allergic fungal rhino sinusitis

Recently one more group is added i.e. Eosinophilic fungal rhinosinusitis.

Acute fulminant invasive sinusitis: The whole duration of illness in these patients is just less than 4 weeks. These patients are mostly immunocompromised individuals. The reduced immunity could very well be a result of

a. Diabetes mellitus

b. AIDS

c. Immunosuppressive medicines

d. Malignancy causing immune suppression

Acute fulminant invasive fungal sinusitis is caused by fungal infections due to:

1. Mucoracea family – seen under microscope as broad hyphae which very rarely septates. Branching out is seen at right angles. This is clearly seen under methanamine / PAS staining of the tissue.

2. Aspergillous family – seen under the microscope as narrow and septate hyphae. Branching could be seen to occur at acute angles.

If mucor is the offending pathogen then it is angioinvasive causing extensive destruction of bone and soft tissue. These patients have a very high mortality rate [3].

Considering the amount of tissue necrosis involved in these patients, surgical debridement followed by intravenous antifungal medications (amphotericin B) is the treatment of choice. This should also be associated with good euglycaemic control. Since granulocytes are necessary in combating this condition, granulocyte transfusion has been attempted [4] with certain degree of success in these patients following wound debridement.

Chronic invasive fungal sinusitis [5]:

This condition is also known as non granulomatous chronic invasive fungal sinusitis. This condition is commonly seen in patients with diabetes mellitus. Feature of this infection is low grade inflammation with tissue necrosis. Usually this disease lasts between 4-6 weeks. Vascular invasion is not seen. Granuloma formation is classically seen. Orbital involvement (Orbital apex syndrome)is common in these patients. This condition affects immunocompetent patients. Fronto ethmoidal region is commonly involved. Maxillary sinus and sphenoid sinus are very rarely affected. More than 80% of these patients have fronto ethmoidal sinus involvement. Aspergillosis have been implicated as the commonest pathogen involved [6].

Orbital apex syndrome is characterized by:

1. Decrease in vision

2. Ocular immobility

3. Proptosis

Ideally these patients are managed by surgical debridement followed by systemic antifungal drugs like amphotericin B infusion.

Chronic invasive fungal sinusitis is rather rare. According to Ferguson (2005) it constitutes less than 0.003% of all forms of fungal sinusitis operated on.

CT scan coronal cut nose and sinuses of a patient with chronic invasive fungal sinusitis with orbital involvement (Note asymmetrical involvement of the sinuses. This is a classic feature of fungal sinusitis)

Granulomatous invasive fungal sinusitis:

This condition is also known as "Indolent fungal sinusitis". Classically these patients have intact cell mediated immune response. These lesions are caused by Aspergillus flavous Clinically this condition is indistinguishable from chronic invasive fungal sinusitis. This is actually a histopathological entity. The intact cell mediated immunity limits the lesion to he surface mucosa. Granulomas could be seen surrounding the fungal elements there by effectively preventing their invasion.

Granulomas typically non caseating and demonstrate the presence of multi-nucleated giant cells and eosinophils. This condition is effectively managed by surgical debridement. After successful wound debridement the intact immune system takes care of the disease. Treatment with itraconazole / vari conazole has shown promising results.
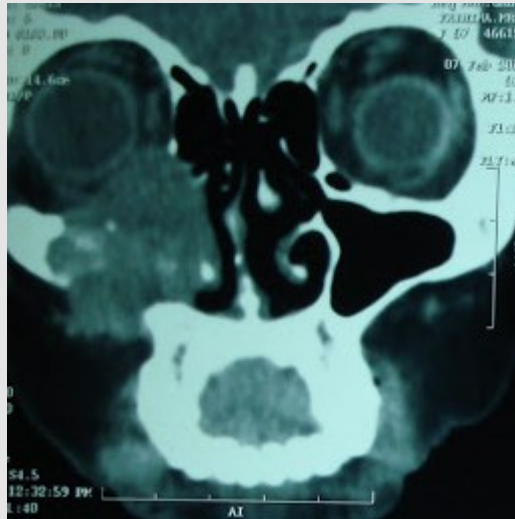
Coronal CT scan image showing hetero dense bone destructive lesion involving right maxillary sinus with destruction of its superior and anterolateral walls. (Note small opaque particles within the mass. These are caused by metallic elements within the fungal mass).

Fungal Ball:

These are also known as mycetomas. Mycetomas commonly present as unilateral opacification of maxillary / sphenoid sinuses. This condition is rather rare in ethmoid and frontal sinuses [7]. Fungal ball is composed of tightly packed hyphae mostly from (aspergillus, alternaria and P. Boydii). This is actually a sequestration of fungal hyphal elements within the sinus without any invasive / granulomatous changes. Nasal mucosa is absolutely normal in these patients. This disease is classically caused due to inhalation of spores, which eventually gets sequestered either into maxillary or sphenoid sinuses.
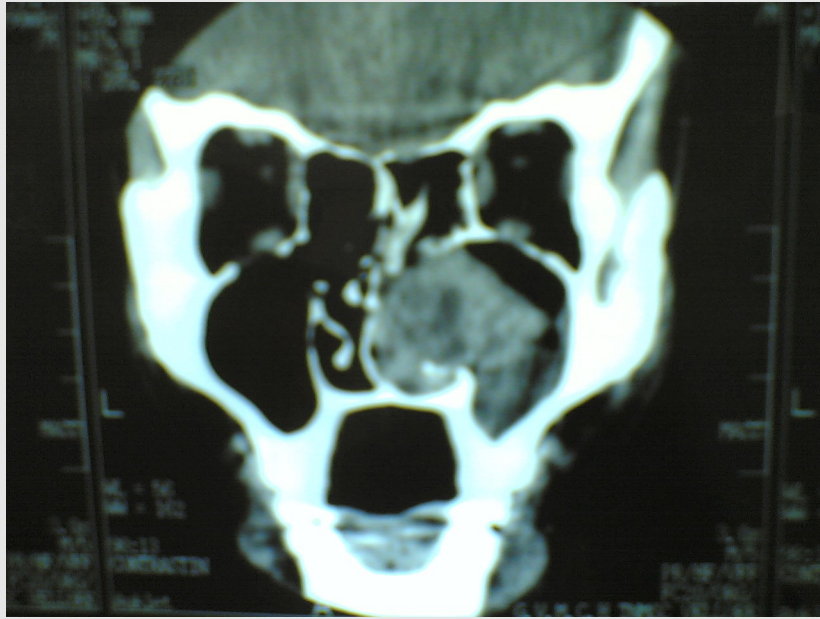
Coronal CT scan of nose and sinuses showing fungal ball within left maxillary sinus cavity

Fungal growth occurs within the confines of the affected

sinus cavity. Fungal growth occurs because of the ability of the infecting pathogen to avoid host immune response. Signs and symptoms may mimic chronic rhinosinusitis in advanced cases.

Clinical examination reveals very little. CT imaging reveals opacity of the involved sinus cavity.

This condition is managed by surgical removal of the fungal ball and creating good ventilation to the involved sinuses by widening the sinus ostium. Systemic antifungal agents are not indicated in these patients. Topical antifugal agents have been administered with varying degrees of success.

In majority of these patients this condition was diagnosed as an incidental finding when routine imaging of nose and sinuses were performed.

Allergic Fungal sinusitis:

This rather poorly understood entity was first reported in 1976 [8]. In 1983 Katzenstein et al described a condition and coined the terminology allergic aspergillus sinusitis. They made the diagnosis based on the presence of histological triad of "clumps / sheets of necrotic eosinophils,

Charcot – Leyden crystals probably from degenerating eosinophils and non invasive fungal hyphae resembling aspergillus species. These patients have a combination of nasal polyposis, crust formation and positive culture for aspergillus. It was Robson in 1989 [9] who introduced the term allergic fungal sinusitis to describe the findings associated with this disease. According to Cody aspergillus species was responsible for only 15% of allergic fungal sinusitis. This was evident from the retrospective study conducted by him covering a large sample size [10].

Incidence of allergic fungal sinusitis among chronic sinusitis is placed around 6-7% [11].

Based on clinical findings Bent and Kuhn proposed certain criteria for diagnosis of allergic fungal sinusitis.

Bent's criteria [12] for the diagnosis of allergic fungal sinusitis:

1. Demonstrable type I hypersensitivity to fungi

2. Nasal polyposis

3. Radiological findings (Heterodense mass lesion)

4. Presence of eosinophilic mucin mixed with non invasive fungus

5. Positive fungal stain / fungal culture

Swain's modification [13] of Bent's criteria:

deShazo and Swain slightly modified the diagnostic criteria laid out by Bent. They left out the type I hypersenitivity criteria alone since only 2/3 of patients with allergic fungal sinusitis manifested with hypersensitivity to fungal protein in various studies.

Bent and Khun modified their diagnostic criteria for diagnosis of allergic fungal sinusitis by adding major and minor diagnostic criteria.

Major Criteria	Minor Criteria
Type I hypersensitivity	Asthma
Nasal Polyposis	Unilateral disease
Characteristic CT findings	Bone erosion
Eosinophilic Mucin	Fungal cultures
Positive fungal stain	Charcot Leyden crystals and eosinophlia

Undisputed diagnostic criteria for the diagnosis of allergic fungal sinusitis include:

1. Chronic rhinosinusitis

2. Presence of allergic mucin

3. Presence of fungal organism within the mucin

Allergic fungal sinusitis like condition:

In this category those patients who do not demonstrate positive fungal presence in the mucin or in cultures of mucin are included. The paucity / absence of fungal elements in these patients could be accounted for by the presence of increased amounts of major basic protein released by eosinophils.

Major basic protein has been found to be toxic to fungi [14].

Clinical features of allergic fungal sinusitis:

These patients present with progressive nasal obstruction, crusting, rhinorrhoea, and chronic rhinosinusitis. These patients can also come with dramatic symptoms like visual loss and total nasal obstruction. Classically radiology shows unilaterally expansile lesion of the sinuses associated with bony erosion. The mass appears as heterodense due to the presence of metallic elements in the fungal hyphae. Unilateral asymmetric involvement of sinuses is the classic feature of this condition [15]. The mechanism of causation of allergic fungal sinusitis is IgE mediated hypersensitivity to fungal proteins especially to aspergillus. Both type I and type III hypersensitivity reactions to fungal proteins have been implicated. Allergic fungal sinusitis still remains an under reported condition due to lack of awareness amongst treating physicians.

Coronal CT nose and sinuses showing Expansile lesion involving the right maxillary sinus. Erosion of medial wall of maxilla, the nasal cavity is filled with heterodense mass. The septum is seen being pushed to the opposite side.

CT scan features of AFRS:

CT scan paranasal sinuses reveal multiple opacified sinuses with central hyper attenuation, mucocele formation, erosion of lamina papyracea / skull base, pushing borders. Bone erosion in patients with nasal polyposis should raise suspicion of allergic fungal sinusitis

Eosinophilic fungal sinusitis:

This terminology was introduced by Ponikau etal to explain pathophysiology of chronic sinusitis.

This disorder is usually bilateral. Fungal hyphae has been demonstrated in almost all these patients. Studies have not managed to demonstrate increased levels of IgE in these patients. Hypersensitivity reaction has been ruled out as a cause for this type of fungal sinusitis. It has been postulated that this condition could be caused by abnormal cell mediated immunity to fungal proteins. These patients respond well to surgical removal of polypoidal mucosa, and creation of wide antrostomy which improves ventilation to the sinus mucosa.

Coronal CT scan of nose and sinuses showing evidence of fungal polyposis inside both nasal cavities with erosion of skull base on the right side. Both maxillary sinuses are obstructed with pent up secretions.

Coronal CT scan of paranasal sinuses (posterior cut) showing opacity of sphenoid sinus with erosion of sphenoid sinus roof. Fungal Sphenoidal sinusitis
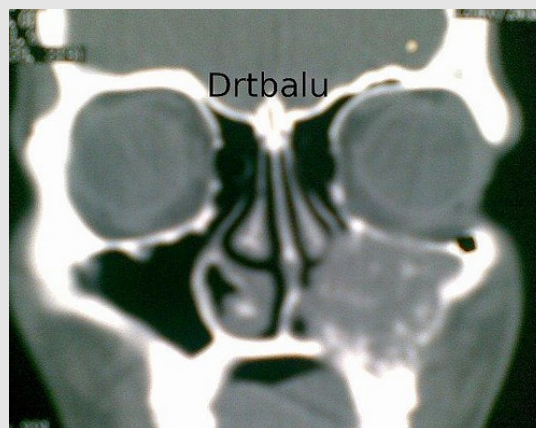
Coronal CT scan nose and sinuses showing fungal sinusitis of maxillary sinus

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Nasal Polyp

Definition:

Polyp is defined as simple oedematous hypertrophied mucosa of the nasal cavity. It can be unilateral / bilateral [1]. Prevalence of nasal polyp in general population has been estimated to be around 4% [2].

Causes of nasal polyp:

1. Infections

2. Allergy

3. Polyp due to mucovisidosis

Classification:

Nasal polyp can be classified as:

1. Simple polyp

. Ethmoidal polypi

. Antrochoanal polyp

2. Fungal polyp

3. Malignant polyp

Imaging plays a crucial role in the diagnosis and management of nasal polypi. The following are some of the important contributions imaging is supposed to make:

 It clinches the diagnosis

It helps in evaluation of progression of disease

Helps in surgical planning

Helps in monitoring for recurrence

CT appearance of nasal polypi [3]:

They appear as rounded bodies of soft tissue arising from the mucosal surfaces of nose and paranasal sinuses. They can be clearly differentiated from the surrounding inflamed mucosal lining and nasal secretion as they are more radio dense and hence appear brighter. Rarely a pedicle attaching the polypoidal mass to the nasal mucosal lining can be seen clearly in the CT scan (pedicle sign). If present it is virtually diagnostic of nasal polypi.

One important point that should be borne in mind while evaluating CT images from a patient with nasal polypi is that they never cause bone erosion. If soft tissue mass arising from the nasal mucosa is associated with bone erosion then it is a definite pointer towards the diagnosis of malignancy. Pressure effects of nasal polyp can be evidently seen in imaging. These effects include local bone remodelling causing a scalloping effect. This scalloping effect should not be confused with that of the scalloping of margins produced by the mucocele since it is always associated with enlargement of the sinus cavity. Rarely this bone remodelling may occasionally cause thinning of the bony septa of the ethmoidal sinus. This thinning could be so extreme that it could go even below that of the resolution of the CT scan. This creates a picture of bone erosion which is not a true one.

Appearance of nasal polyp when contrast CT is taken:

Nasal polypi do not show enhancement on injection of contrast media. The mucosa surrounding the nasal polyi may show enhancement causing an impression of rim enhancement around the nasal polypi.

Types of nasal polyp:

Ethmoidal polypi – arising from ethmoidal sinus and are multiple. They can be visualized in the CT scan of paranasal sinuses as multiple polypoid lesions. Polypi arising close to the cribriform plate area can cause olfactory disturbances.

Polyp arising from the maxillary sinus – is usually solitary.

It exits the antrum via the natural / accessory ostium. This causes an enlargement of ostia. Radiologically it appears like a dumbbell because of the constriction present in the midline (ostial exit point). In these patients the medial wall of the maxillary sinus bows into the nasal cavity. This can be clearly visualized in the CT scan images. Obstruction caused by this polyp to the drainage channels of ethmoidal and frontal sinuses (middle meatus) can cause opacification of those sinuses also there by making it difficult to identify the exact origin of the nasal polyp. In this scenario the bone remodelling that takes place in the medial wall of maxillary sinus could be the clincher. If these polyp passes posteriorly to exit via the choana it could be clearly visualized in the axial cuts taken at the choanal level.

Fungal disease may coexist with nasal polypi. If present they could be visualized as hyper dense areas between the nasal polypi shadows.

CT differences between acute sinusitis & nasal polypi [4]:

Acute sinusitis causes a near uniform Opacification of the paranasal sinuses whereas nasal polypi in addition to the Opacification show multiple convexities.

Mucous retention cyst can be safely eliminated if the polyp shows a pedicle radiologically. If there is associated bone remodelling then in all probability it could be nasal polyp rather than mucous retention cyst. In case of diagnostic dilemma MRI will clinch the diagnosis.

In cystic fibrosis in addition to the radio densities seen in the CT scan images there is also associated thickening of the maxillary sinus walls due to osteoneogenesis.
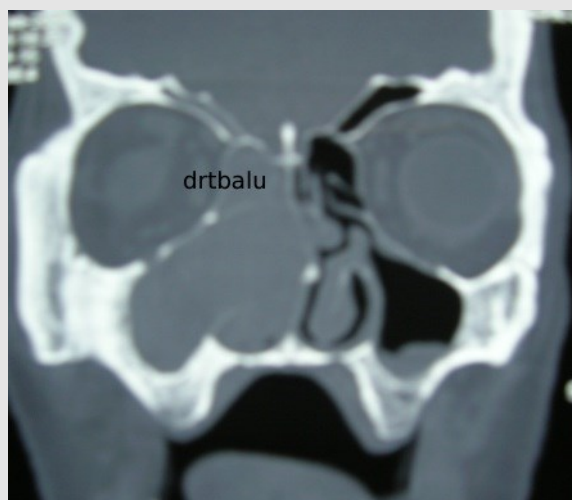
Coronal CT showing nasal polyposis with bone remodelling

Differences between ethmoidal polypi and antrochoanal polyp

Ethmoidal Polypi	Antrochoanal polyp
Seen in adults	Seen in children and adolescents
Allergy is the common cause	Infection is the common cause
Multiple and bilateral (appears like a bunch of grapes)	Unilateral and single
Arises from ethmoidal labyrinth	Arises from maxillary antrum
Seen in anterior rhinoscopy	Seen during post nasal examination
X-ray sinuses shows normal antrum and hazy ethmoids	X-ray sinuses show hazy antrum
Recurrence is common	Recurrence is uncommon

Antrochoanal polyp [5]:

Synonyms: Antrochoanal polyp, Killian's polyp, Nasal polyp.

History: In 1753 Palfyn first described an antrochoanal polyp in a female patient.

The polyp was found filling the nasopharynx extending up to the uvula of the patient. Palfyn believed that this polyp arose from the choana. It was Killian in 1906 who demonstrated that this polyp arose from the maxillary sinus antrum.

Definition: Antrochoanal polyp is a benign solitary polypoidal lesion arising from the maxillary sinus antrum causing opacification and enlargement of antrum radiologically without any evidence of bone destruction. It exits the antrum through the accessory ostium reaches the nasal cavity, expands posteriorly to exit through the choana into the post nasal space.

Incidence: It commonly affects children and young adults.

Etiopathogenesis: This disease is commonly seen only in non atopic persons. Its etiology is still unknown. In fact this disorder is not associated with nasal allergy.

Proetz theory: Proetz suggested that this disease could be due to faulty development of the maxillary sinus ostium, since it was always been found to be large in these patients. Hypertrophic mucosa of maxillary antrum sprouts out through this enlarged maxillary sinus ostium to get into the nasal cavity. The growth of the polyp is due to impediment to the venous return from the polyp. This impediment occur at the level of the maxillary sinus ostium. This venous stasis increases the oedema of the polypoid mucosa thereby increasing its size.

Bernoulli's phenomenon: Pressure drop next to a constriction causes a suction effect pulling the sinus mucosa into the nose.

Mucopolysaccharide changes: Jakson postulated that changes in mucopolysaccharides of the ground substance could cause nasal polyp.

Infections: Recurrent nasal infections have also been postulated as the cause for nasal polyp.

Mill's theory:

Mills postulated that Antrochoanal polyp could be maxillary mucoceles which could be caused due to obstruction of mucinous glands.

Ewing's theory:

Ewings suggested that an anomaly which could occur during maxillary sinus

development could leave a mucosal fold close to the ostium. This fold could later be aspirated into the sinus cavity due to the effects of inspired air causing the development of antrochonal polyp.

Vasomotor imbalance theory: This theory attributes polyp formation due to

autonomic imbalance Polypoidal tissue from the maxillary antrum exits out through the accessory maxillary sinus ostium according to some workers. This accessory sinus ostium is placed posteriorly, which could be the reason for the polyp to present posteriorly. The accessory sinus ostium widens progressively, ultimately at one stage merging with the natural ostium of the maxillary sinus forming one huge opening into the maxillary antrum.

Infection / Inflammation:

This theory suggests that acinous mucous glands within the maxillary sinus cavity gets blocked due to infection / inflammation involving the mucous lining of the sinus cavity. This leads to the formation of a cystic lesion within the maxillary sinus cavity. This cyst gradually enlarges to occupy the whole of the maxillary sinus cavity. It exits the sinus cavity by enlarging the accessory ostium and enters the nasal cavity. Usually these cysts arise from the antero inferior / medial wall of maxillary antrum.

Possible reasons for migration of Antrochoanal polyp in to the post nasal space:

1. The accessory ostium through which the polyp gets out of the maxillary antrum is present posteriorly.

2. The inspiratory air current is more powerful than the expiratory air current thereby pushes the polyp posteriorly.

3. The natural slope of the nasal cavity is directed posteriorly, hence the polypalways slips posteriorly.

4. The cilia of the ciliated columnar epithelial cells lining the nasal cavity always beats antero posteriorly pushing the polyp behind.

Histology: Shows respiratory epithelium over normal basement membrane. The interstitial layer is grossly oedematous, with no eosinophils. The interstial layer contains other inflammatory cells.

Clinical features: Since the disorder is unilateral (commonly) the patient always present with:

1. Unilateral nasal obstruction

2. Unilateral nasal discharge

3. Headache (mostly unilateral)

4. Epistaxis

5. Sleep apnoea

6. Rhinolalia clausa due to presence of polyp in the post nasal space

7. Difficulty in swallowing if the polyp extends into the oropharynx


Anterior rhinoscopy image of Antrochoanal polyp

CT scan of paranasal sinuses is diagnostic. It will show the polyp filling the maxillary antrum and exiting out through the accessory ostium into the nasal cavity.
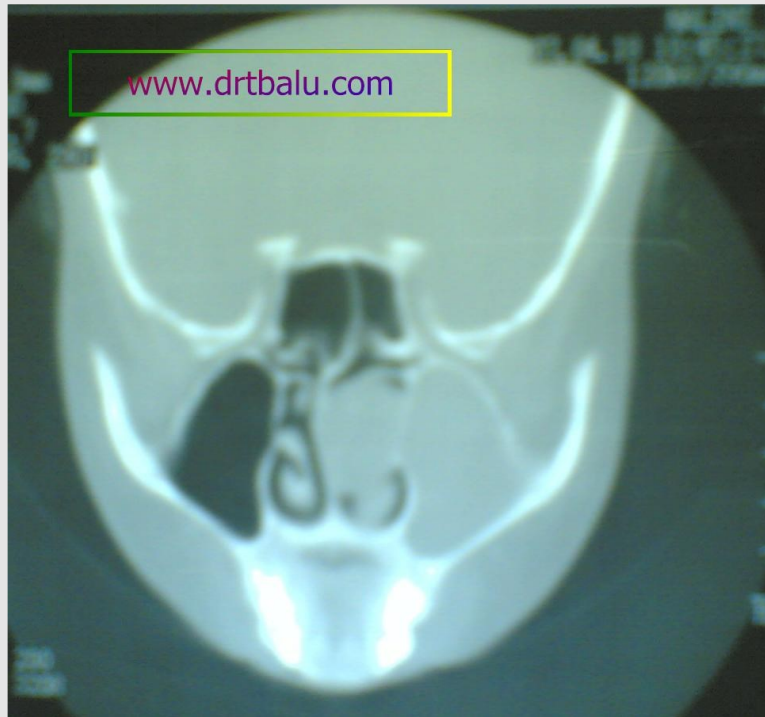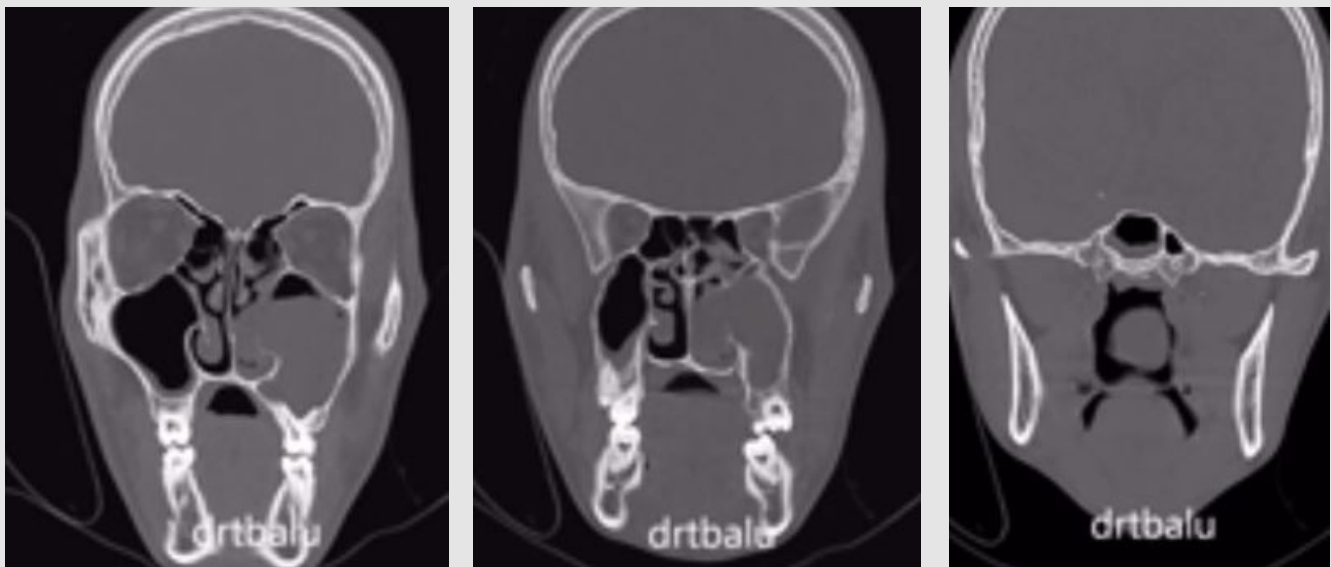

Coronal CT of nose and sinuses showing Antrochoanal polyp. (Note the antral component and the nasal component

Endoscopic view of choanal component of Antrochoanal polyp
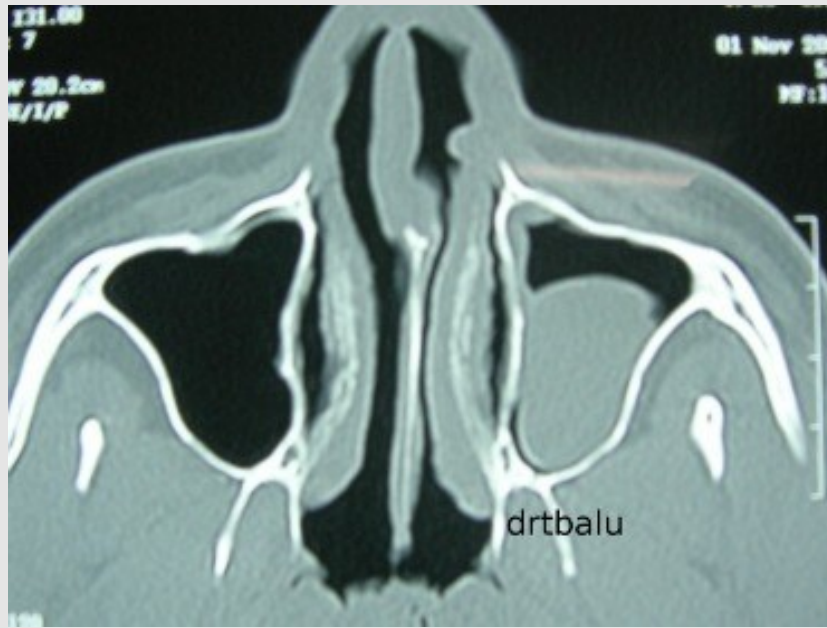
Mucous retention cyst maxillary antrum which could be a precursor to Antrochoanal polyp

Serial Coronal CT images showing Antrochoanal polyp

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2. Nasal polyp: Polyp is a Latin word meaning polypous (many footed). Hedman J, Kaprio J, Poussa T, et al. 1999. Prevalence of asthma, aspirin intolerance, nasal polyposis and chronic obstructive pulmonary disease in a population-based study. Int J Epidemiol, 28:717–22.

3. http://www.drtbalu.co.in/image_naslpolyp.html

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5. https://www.scribd.com/doc/48796994/ac-polyp#

Role of imaging in Faciomaxillary trauma

Imaging plays a vital role in assessment of the severity of Faciomaxillary trauma. Properly performed CT imaging reveals not only the exact fracture site but also helps the surgeon in deciding the optimal management modality. The entire facial skeleton is supported by two buttresses, one horizontal and one vertical [1]. These buttresses play an important role in absorbing deforming forces of injury.

The buttress system of midface is formed by strong frontal, maxillary, zygomatic and sphenoid bones and their attachments to one another. The central midface contains many fragile bones that could easily crumble when subjected to strong forces. These fragile bones are surrounded by thicker bones of the facial buttress system lending it some strength and stability. Components of Buttress system:

For better understanding the components of the facial buttress system have been divided into:

1. Vertical buttresses

2. Horizontal buttresses

Vertical buttress: These buttresses are very well developed.

They include:

1. Nasomaxillary

2. Zygomaticomaxillay

3. Pterygomaxillay

4. Vertical mandible

Majority of the forces absorbed by midface are masticatory in nature. Hence the vertical buttresses are well developed in humans.

Horizontal buttresses:

These buttresses interconnect and provide support for the vertical buttresses. They include:

1. Frontal bar

2. Infraorbital rim & nasal bones
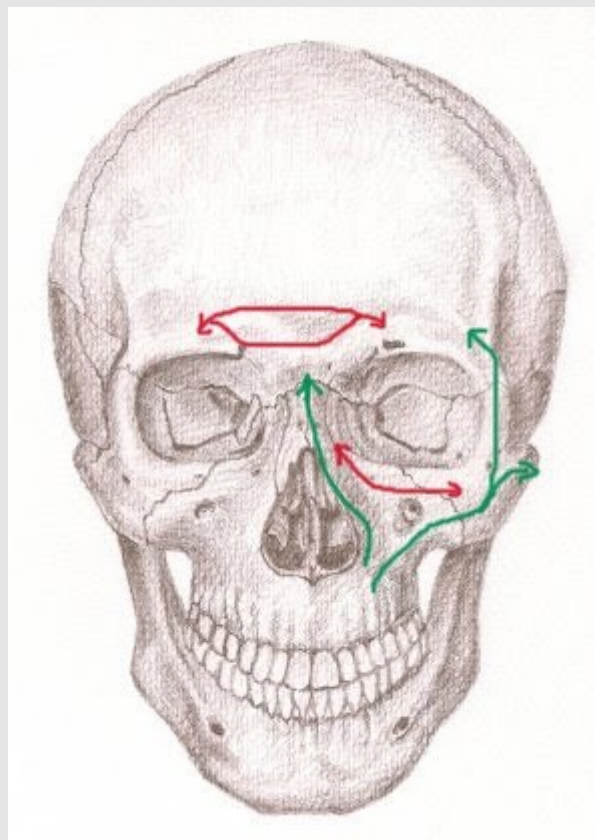
3. Hard palate & maxillary alveolus

Figure showing various buttresses of midface

Fracture nasal bones:

Nose is the most prominent part of the face, hence it is likely to be the most common structure to be injured in the face. Although fractures involving the nasal bones are very common, it is often ignored by the patient. Patients with fractures of nasal bone will have deformity, tenderness, hemorrhage, edema, ecchymosis, instability, and crepitation. These features may be present in varying combinations.
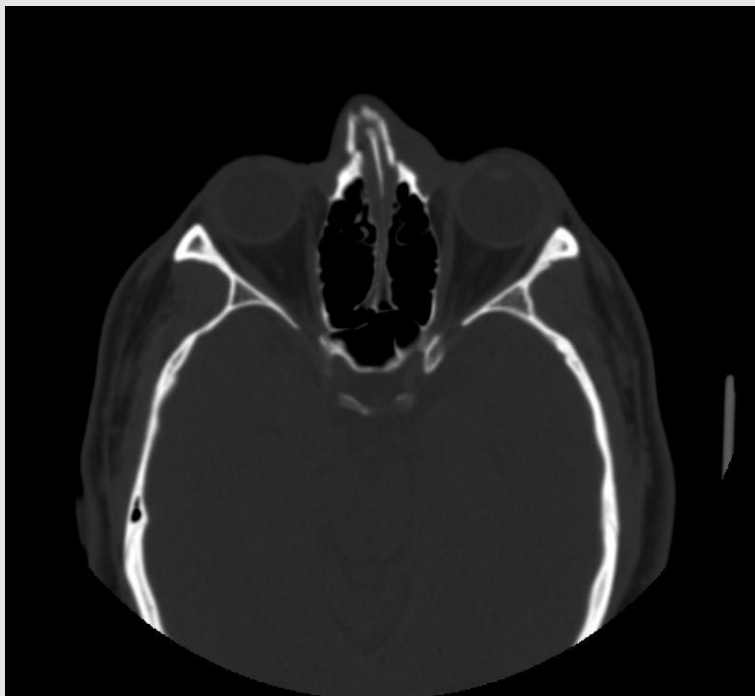
Axial CT of nose and sinuses showing fracture of both nasal bones

Nasal bone fractures are common because:

1. Nose happens to be the most prominent portion of the face

2. Increasing number of road traffic accidents [2]

3. Increasing incidence of domestic violence [3]

4. Increase in the number of individuals taking part in contact sports

Nasal bones are paired bones. Both these bones project like a tent on the frontal process of maxilla. In the midline they articulate with one another. Just under this midline articulation lies the nasal septum. Superiorly the nasal bones are thicker where it articulates with the nasal process of frontal bone. This area is relatively stable and firm. Nasal bone fractures commonly occur at the transition zone between the proximal thicker and distal thinner portions. This zone precisely corresponds to the lower third of the nasal bone area. Fractures involving nasal bones if not properly and promptly treated leads to:

1. Nasal deformities

2. Intranasal dysfunction like nasal block

Fracture nasal bone is known to cause higher incidence of morbidity and complications when compared that of fractures involving other facial bones [4]. In order to treat this condition properly it is necessary to accurately diagnose this condition by:

1. Looking for crepitus and tenderness over the nasal bone area

2. Radiographic evaluation of nasal bones. Radiography helps in diagnosis and classification of nasal bone fractures, and also in checking the adequacy of reduction [5].

Pathophysiology:

The following points should be borne in mind before attempting to understand the pathophysiological factors that lead to fractures involving nasal bones.

1. Nasal bones and underlying cartilage are susceptible for fracture because of their more prominent and central position in the face.

2. These structures are also pretty brittle and poorly withstands force of impact.

3. The ease with which the nose is broken may help protect the integrity of the neck, eyes, and brain. Thus it acts as a protective mechanism.

4. Nasal fractures occur in one of two main patterns- from a lateral impact or from a head on impact. In lateral trauma, the nose is displaced away from the midline on the side of the injury, in head-on trauma, the nasal bones are pushed up and splayed so that the upper nose (bridge) appears broad, but the height of the nose is collapsed (saddle-nose deformity). In both cases, the septum is often fractured and displaced.

5. The nasal bone is composed of two parts: A thick superior portion and a thin inferior portion. The intercanthal line demarcates these two portions. Fractures commonly occur below this line.

4. Nasal fractures occur in one of two main patterns- from a lateral impact or from a head on impact. In lateral trauma, the nose is displaced away from the midline on the side of the injury, in head-on trauma, the nasal bones are pushed up and splayed so that the upper nose (bridge) appears broad, but the height of the nose is collapsed (saddle-nose deformity). In both cases, the septum is often fractured and displaced.

5. The nasal bone is composed of two parts: A thick superior portion and a thin inferior portion. The intercanthal line demarcates these two portions. Fractures commonly occur below this line.

6. Nasal bones undergo fracture in its lower portion and seldom the upper portion is involved in the fracture line. This is because the upper portions of the nasal bone is supported by its articulation with the frontal bone and frontal process of maxilla.

7. Because of the close association between nasal bone and the cartilaginous portions of the nose, and the nasal septum it is quite unusual for pure nasal bone fractures to occur without affecting these structures. If closed reduction alone is performed to reduce nasal bone fractures without correction of nasal septal fractures, this could cause progressive nasal obstruction due to uncorrected deviation of nasal septum. This is because of the tendency of the nasal septum to heal by fibrosis which causes bizarre deviations like "C" "S" etc. Since nose is the most prominent portion of the face, its supporting bony structures have low breaking strength the naso ethmoidal complex fractures when exposed to forces of about 80 grams. This fact was demonstrated by Swearinger in 1965.

Axial CT of nose and sinuses showing buckling of nasal septum due to fracture involving nasal bones
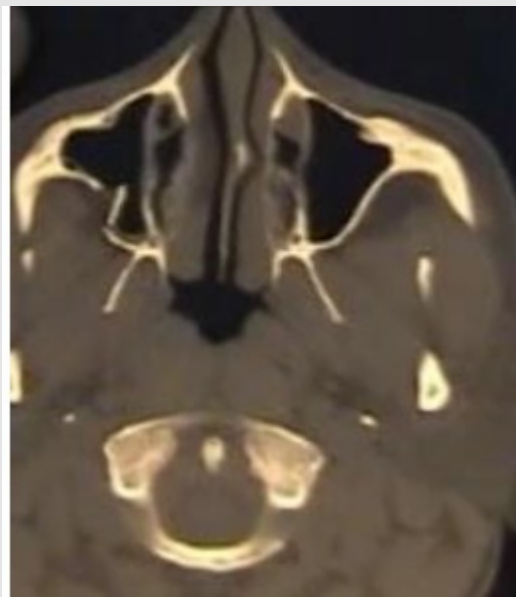
Fracture zygoma:

Zygoma is a very crucial component which maintains facial contour. Fractures involving zygoma is very common, in fact it is the second most common facial bone to the fractured following facial trauma (next only to nasal bones). Fractures involving maxilla not only creates cosmetic deformities, it also causes disruption of ocular and mandibular functions too. The bony architecture of this bone is rather unique, it enables it to withstand blows with significant impact without being fractured. At the most it gets disarticulated along its suture lines. Fractures can involve any of the four articulations of zygoma which include zygomatico-maxillary complex, zygomatic complex proper, orbitozygomatic complex. Fractures involving zygoma should be repaired at the earliest because it can cause both functional and cosmetic defects. Important functional defects involving this bone is restriction of mouth opening due to impingement on the coronoid process[6]. It is hence mandatory to diagnose and treat this condition properly. It is also important to reduce this fracture and fix it accurately, because skeletal healing after inadequate reduction can cause reduced projection of malar region of the face leading on to cosmetic deformities. Accurate assessment of position of the fractured bone should be performed in relation to skull base posteriorly and midface anteriorly. This assessment is very important before reduction is attempted to ensure accurate reduction of the fractured fragments.

Classification of zygoma fracture:

Leefort classification:

1. Non displaced – Symptomatic treatment. No reduction necessary

2. Displaced – Closed reduction is necessary

3. Comminuted – Open reduction is necessary

4. Orbital wall fracture – If ocular symptoms predominate it should be attended first. After oedema subsides then open reduction can be attempted.

5. Zygomatic arch fracture – Open reduction with stablization using micro plates / wiring.

CT image of nose and sinuses showing fracture of zygoma with medial displacement

Knight & North classification [7]:

This classification suggested by Knight etal in 1961 helped to determine prognosis and optimal treatment modality for these individuals.
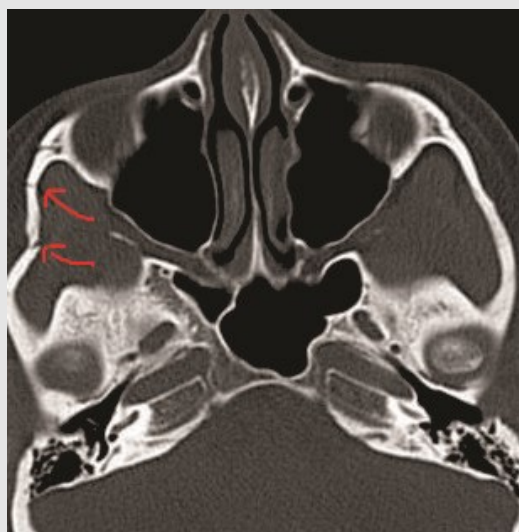
Group I fractures:

In these patients fracture lines in zygoma could be seen only in imaging. There is absolutely no displacement. These patients could ideally be managed conservatively by observation and by asking the patient to eat soft diet.
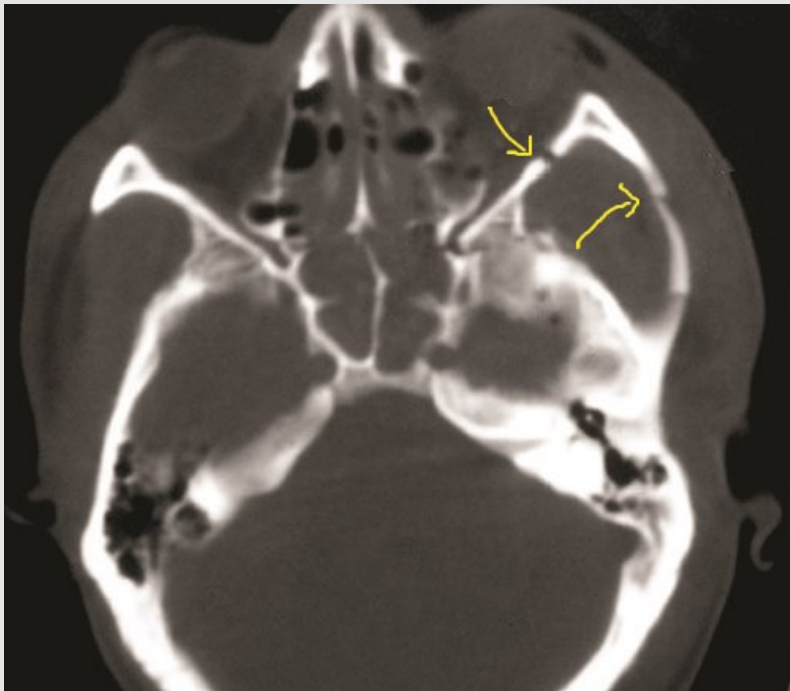
Axial CT of nose and sinuses showing fracture lines involving zygoma (yellow arrows)
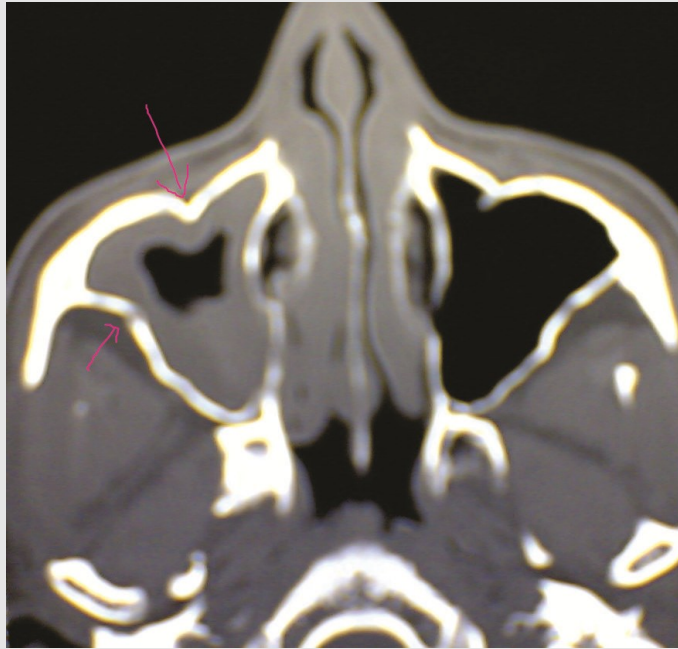
Group II fractures:

This group includes isolated fractures of the arch of zygoma. These patients present with trismus and cosmetic deformities.

Axial CT of nose and sinuses showing fracture of arch of zygoma (red arrows)

Group III fractures:

This include unrotated fractures involving body of zygoma.

Axial CT scan showing Fracture involving body of zygoma. Note there is no displacement of body of zygoma
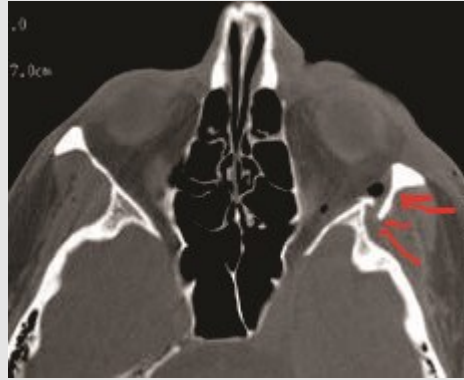
Group IV fractures:

This involves medially rotated fractures of body of zygoma.

Axial CT showing medially rotated fractured body of zygoma

Group V fractures:

This involves laterally rotated fractures of body of zygoma. This type of fracture is very unstable and cannot be managed by closed reduction. Open reduction will have to be resorted to.

Axial CT image showing fracture body of zygoma with unstable lateral rotation

Group VI fractures:

This is complex fracture. It has multiple fracture lines over the body of zygoma. This condition is difficult to manage by closed reduction. Open reduction and microplate fixation is indicated in these patients. This type of fracture should not be managed by closed reduction alone because the presence of oedema / hematoma would mask the cosmetic deformity giving an impression that reduction has occurred. After reduction of oedema and followed by the action of masseter the fractured fragment may distract making the cosmetic deformity well noticeable.
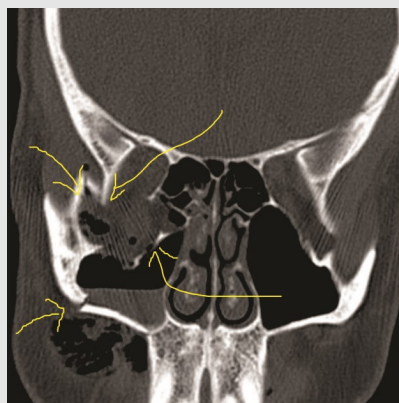
Coronal CT of nose and sinuses showing multiple fractures involving zygoma

Blow out fracture:

Blow out fracture of orbit involves fracture of orbital floor without fracture of infraorbital rim. This injury is common from frontal blow to orbit. Frontal blow to orbit causes increased intraorbital tension causing fracture of floor of the orbit (weak point) with prolapse of orbital content into the maxillary sinus cavity. This causes enophthalmos and diplopia.

Infraorbital rim is not involved in pure blow out fracture, it is also involved then it should be considered as an impure blow out fracture[8]. Entrapment of inferior rectus muscle between the fracture fragments will cause diplopia in these patients

CT nose and sinuses coronal section showing blow out fracture. Note prolapse of orbital fat into the maxillary sinus (Tear drop sign)

Two theories attempt to explain this injury phenomenon:

1. Buckling theory

2. Hydraulic theory

Buckling theory:

This theory proposed that if a force strikes at any part of the orbital rim, these forces gets transferred to the paper thin weak walls of the orbit (i.e. floor and medial wall) via rippling effect causing them to distort and eventually to fracture. This mechanism was first described by Lefort.

Hydraulic theory [9]:

This theory was proposed by Pfeiffer in 1943. This theory believes that for blow out fracture to occur the blow should be received by the eye ball and the force should be transmitted to the walls of the orbit via hydraulic effect. So according to this theory for blow out fracture to occur the eye ball should sustain direct blow pushing it into the orbit.

Water House [10] in 1999 did a detailed study of these two mechanisms by applying force to the cadaveric orbit. He in fact used fresh unfixed cadavers for the investigation. He described two types of fractures:

Type I: A small fracture confined to the floor of the orbit (actually mid medial floor) with herniation of orbital contents in to the maxillary sinus. This fracture was produced when force was applied directly to the globe (Hydraulic theory).

Type II: A large fracture involving the floor and medial wall with herniation of orbital contents.

This type of fracture was caused by force applied to the orbital rim (Buckling theory).

Initial signs and symptoms of blow out fracture include:

1. Immediate swelling of the eye

2. Tenderness over involved orbit

3. Pain and difficulty with eye movements

4. Double vision

5. Enopthalmos

6. Numbness / tingling over lower eyelid, nose, and upper lip [11]

Complications of blow out fracture:

1. Herniation of orbital fat into maxillary sinus [12]

2. Orbital emphysema [13]

3. Bleeding into maxillary sinus

4. Entrapment / rupture of ocular muscles

5. Ischemic muscle contractures

6. Cellulitis

7. Diplopia
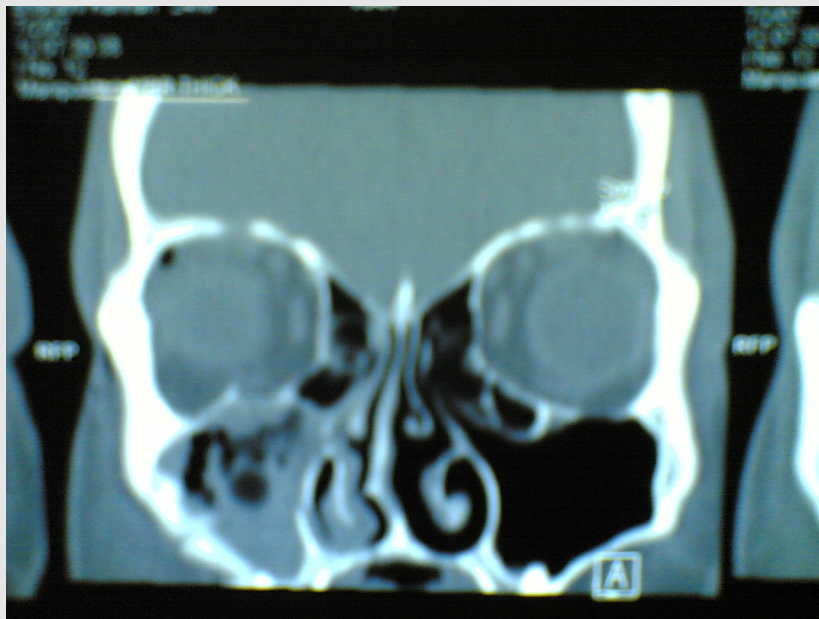
Coronal CT shows blow out fracture right orbit with hemosinus of right maxillary antrum

Axial CT image showing fracture of antero lateral wall of right maxilla
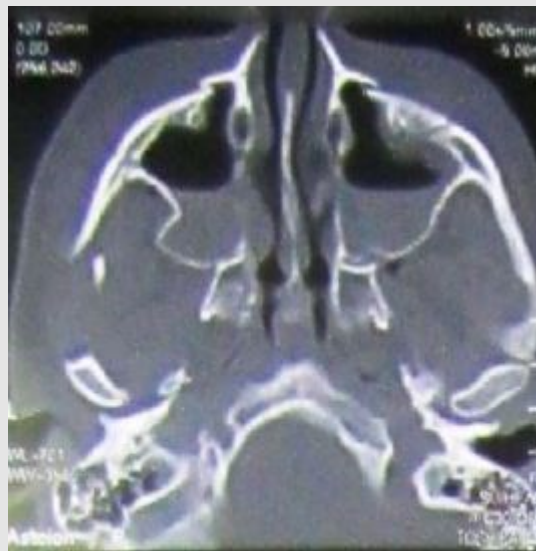
Axial CT of nose and sinuses showing fracture involving anterolateral wall of both maxillary sinus. Note hemosinus of both maxillary sinuses

Fracture frontal sinus:

Fractures involving frontal bone is rather rare because of its protected location [14]. It is basically protected from trauma by the prominence formed by the nasal pyramid. Incidence of fractures involving this area ranges between 5-15% 3 Fractures involving this bone is considered to be rather dangerous because of its proximity to brain as well as due to the cosmetic defects it can produce. The proximity of this bone to the orbit and naso frontal duct doesn't help matters either. Fractures involving this area if not treated promptly can

lead to[15]:

1. Meningitis

2. Mucopyocele

3. Encephalitis

4. Cerebral abscess

It should be borne in mind that all cases of fractures involving frontal bone should be considered as a potential head injury and should be managed similarly because of its close proximity to the brain.

Causes of frontal sinus injuries:

1. Road traffic accident

2. Assault

3. Industrial accidents

4. Recreational accidents

Classification of frontal bone fractures:

Anterior table fracture

1. With / without displacement

2. With / without outflow tract injury

Posterior table fracture commonly occurs in combination with anterior table fracture

1. With / without displacement

2. With / without dural injury / CSF leak

3. With / without outflow tract injury

Displacement is considered to be present if it is about the width of one table of the frontal bone.

Clinical presenting features:

These include:

1. Cosmetic defect

2. Headache

3. CSF leak (in patients with posterior table fractures)
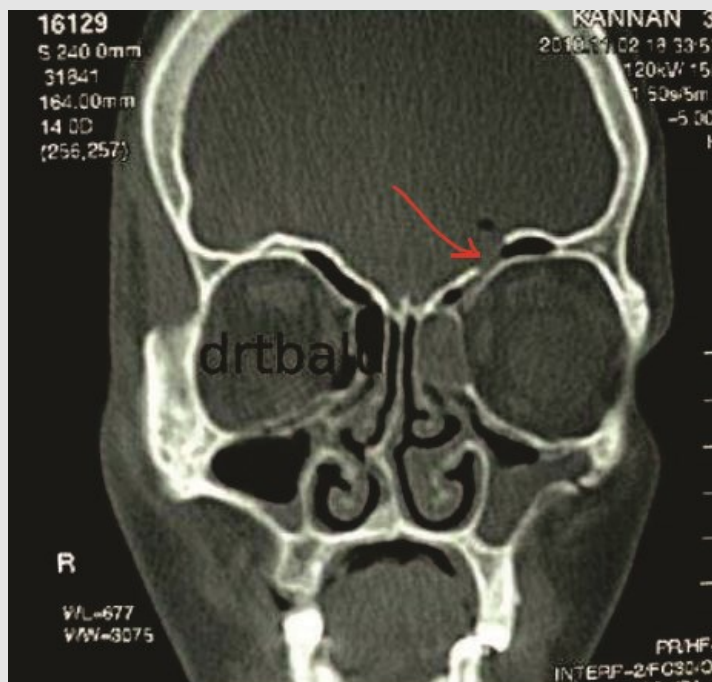
Coronal CT nose and sinuses showing fracture involving posterior table of frontal sinus (red arrow)

CT image showing depressed fracture of anterior table of frontal sinus

Coronal CT of nose and sinuses showing fracture involving the foveal angle (arrow)

References:
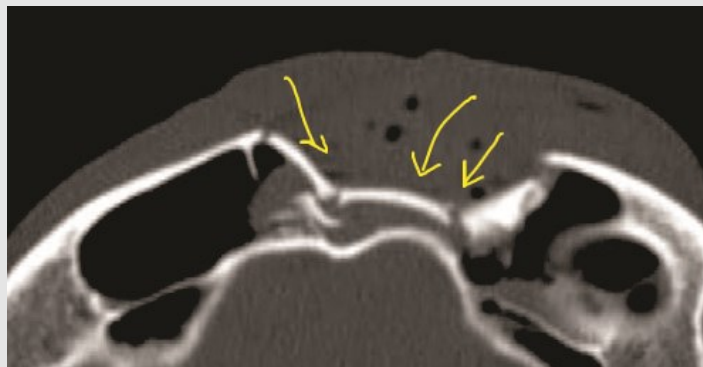
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Fibrous dysplasia of Faciomaxillary region

Fibrous dysplasia is a benign slow growing fibro-osseous disease characterized by replacement of normal bone with varying degrees of fibrous tissue / immature woven bone. This was first described by Lichtenstein in 1938[1] who called it "perverted activity of bone forming mesenchyme".

Classification of fibrous dysplasia[2] :

1. Monostotic variety – Involving single bone

2. Polyostotic variety – Involving multiple bones

3. McCune-Albright syndrome – Characterized by polyostotic fibrous dysplasia in association with hyperfunctional endocrinopathies (precocious puberty, hyperthyroidism, or acromegaly) and cafe au lait spots involving the skin.

Classic epidemiological features of this disorder include:

1. It accounts for about 10% of all bony tumors[3]

2. Monostotic variety is ten times more prevalent than polyostotic variety

3. Majority of monostotic fibrous dysplasia manifest during the first three decades of life

4. Polyostotic fibrous dysplasia presents early during childhood

5. McCune-Albright syndrome also manifests during early childhood.

6. Among facial bones commonest to be involved is ethmoid, followed by frontal and maxilla[4].

Pathophysiology:

Intramedullary lesions grossly appear as well circumscribed tumors varying greatly in size. Large intramedullary lesions tend to cause bone expansion and distortion.

Microscopic appearance: These lesions appear as irregular trabeculae of woven immature bone.

They resemble Chinese characters. These lesions are surrounded by normal bone and covered by cellular fibrous stroma with osteoblast progenitor cells closely resembling fibroblasts.

In fibrous dysplasia bone marrow stromal cell differentiation is arrested. This leads to proliferation of immature cells causing the characteristic fibrous dysplasia.[5]

The exact molecular etiology causing this problem has been identified as somatic missense mutation involving GNAS 1 gene on chromosome 20.[7] This gene is responsible for encoding ά subunit of stimulatory G protein coupled receptor Gs ά. In fibrous dysplasia cells arginine is replaced by either cysteine / histidine. This results in inhibition of intrinsic GTPase activity of Gs ά protein. This causes independent activation and accumulation of Cyclic AMP. In bone this causes an effect similar to that of continuous parathormone stimulation. Growth of fibrous dysplasia is enhanced in the presence of growth stimulating hormones. Growth rate of fibrous dysplasia decreases with age as the growth stimulating hormone levels decrease.[6]

Clinical features of fibrous dysplasia:

Clinical features are largely dependent on compression of adjacent structures.

1. Asymptomatic painless bony enlargement causing deformity and asymmetry

2. Headache

3. Blurring of vision

4. Visual field defects

5. Diplopia

6. Hearing loss

7. Epiphora

8. Eyelid position abnormalities

Non skeletal manifestations of Fibrous dysplasia:

1. Abnormal cutaneous pigmentation (Jagged "coast of Maine" border

2. Precocious puberty

3. Hyperthyroidism

4. Cushing's disease

5. Hyperparathyroidism

6. Hypophosphatemic rickets

Role of radiology in the diagnosis of fibrous dysplasia:

Majority of fibrous dysplasia are asymptomatic but for the asymmetry caused by the lesion. Since these tumors are very slow growing ones, it could take a long time before the effects of neurovascular compression begin to take place.

Radiological diagnosis alone would suffice for all patients with monostotic fibrous dysplasia. But polyostotic fibrous dysplastic lesions should always be biopsied for histopathological correlation.

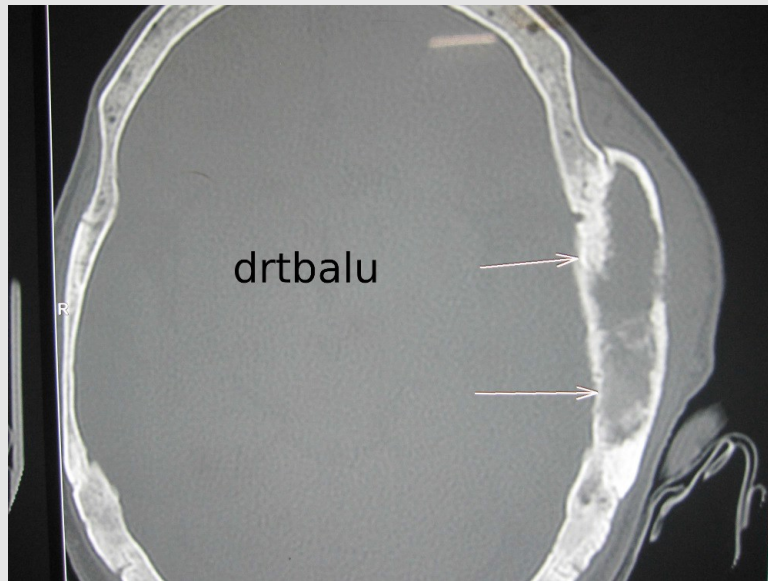CT appearance of fibrous dysplasia:

Commonly the lesion appears like ground glass – 50-60%

Homogenous dense pattern – seen in 20-30%
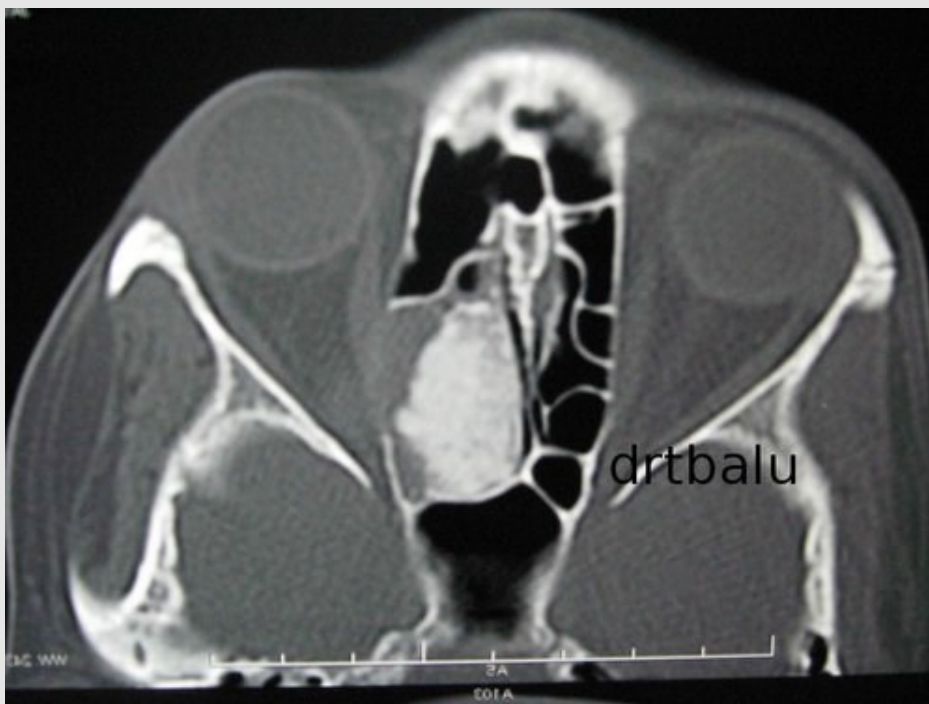
Cystic pattern – Seen in 10-20% of cases

CT coronal cut of nose and paranasal sinuses showing fibrous dysplasia of left maxilla.
This is the classic homogenous dense pattern

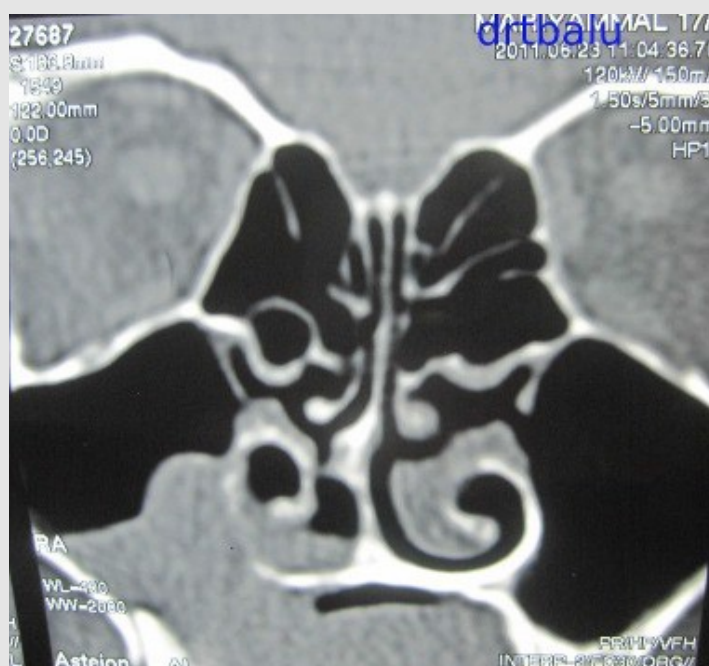CT scan showing fibrous dysplasia of zygoma

Axial CT showing fibrous dysplasia involving posterior ethmoid cells (ground glass type) on the right side. Note the lesion is seen compressing optic nerve

Chen & Noordoff classification 20 of craniofacial fibrous dysplasia:

1. Zone I : Fibrous dysplasia involving fronto orbital, zygomatic and upper portions of maxilla

2. Zone II: Fibrous dysplasia involving cranium (in its hair bearing area)

3. Zone III: Fibrous dysplasia involving the central portion of skull base

4. Zone IV: Fibrous dysplasia involving teeth bearing regions of maxilla and mandible.

This classification helps in deciding the management modality.

Clinical photograph and CT scan image from a patient with zone IV fibrous dysplasia.

Axial CT showing fibrous dysplasia of ethmoids (Note ground glass appearance)

Coronal CT image showing fibrous dysplasia of ethmoid with attachment to skull base

Coronal CT showing fibrous dysplasia of orbit with involvement of skull base
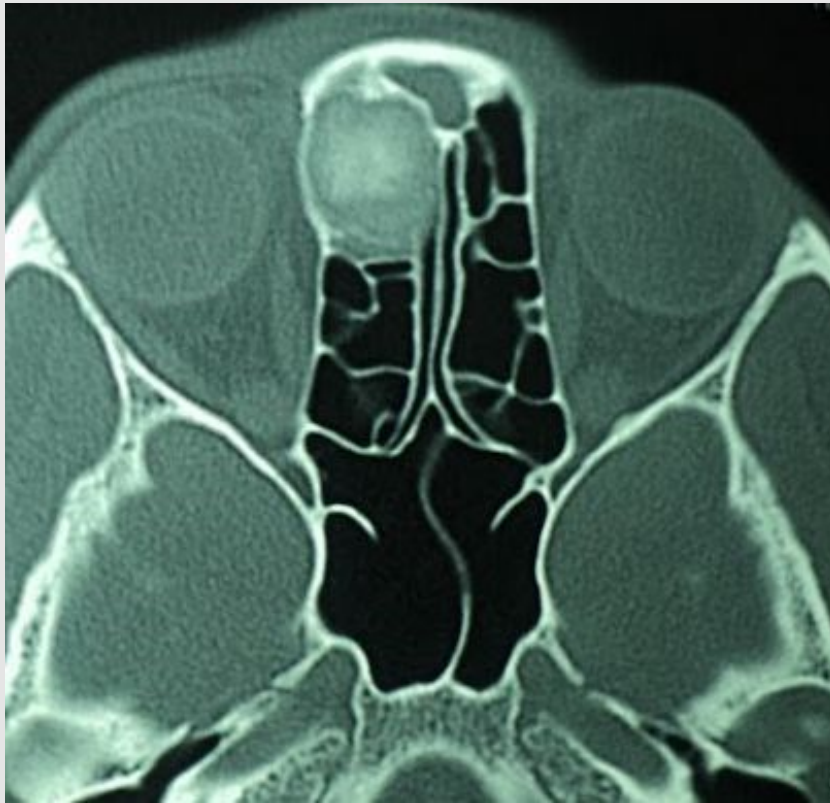
Axial CT of nose and sinuses showing fibrous dysplasia involving anterior ethmoid.

Coronal CT image showing fibrous dysplasia involving anterior ethmoid extending into the orbit. Not frontal sinus drainage area is compromised

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Atrophic Rhinitis

Introduction:

Atrophic rhinitis is defined as a chronic nasal disease characterized by progressive atrophy of the nasal mucosa along with the underlying bones of turbinates. There is also associated presence of viscid secretion which rapidly dries up forming foul smelling crusts. This fetid odor [1] is also known as ozaena. The nasal cavity is also abnormally patent. The patient is fortunately unaware of the stench emitting from the nose as this disorder is associated with merciful anosmia [2]. This disease is rather rare in developed countries, but are rather common in developing countries [3]. Now a days it is more common as a sequelae of medical interventions. Overzealous turbinate surgery has been implicated as a probable iatrogenic cause [4].

Synonyms:

The following are the various terminologies used to indicate the same condition:

1. Rhinitis sicca

2. Dry rhinitis

3. Ozena

4. Open nose syndrome

5. Empty nose syndrome

Etiology:

The etiology of this problem still remains obscure. Numerous pathogens have been associated with

this condition, the most important of them are:

1. Coccobacillus

2. Bacillus mucosus

3. Coccobacillus foetidus ozaenae

4. Diptheroid bacilli

5. Klebsiella ozaenae.

These organisms despite being isolated from the nose of diseased patients have not categorically been proved as the cause for the same.

Other predisposing factors include:

1. Chronic sinusitis SSali [5] considered atrophic rhinitis to be infective in nature. He reported atrophic rhinitis in 7 children of a family after a child with atrophic rhinitis spent a night in their house. Common organism isolated from nasal cavities of these children was Klebsiella ozenae

2. Excessive surgical destruction of the nasal mucosa and turbinates

3. Nutritional deficiencies: Bernat [6] in 1965 demonstrated that 50% of patients with atrophic rhinitis benefited with iron therapy. Hansen demonstrated symptomatic improvement in majority of this patients with atrophic rhinitis when treated with vitamin A.

4. Syphilis.

5. Endocrine imbalances (Disease is known to worsen with pregnancy / menstruation)

6. Heredity: This was first reported by Barton [7] and Sibert (Autosomal dominent pattern of inheritance identified).

7. Autoimmune disease

8. Developmental: Hagrass [7] reported shortened Antero Posterior nasal lengths and poor maxillary antral pneumatization in patients with atrophic rhinitis.

9. Vascular: Excess sympathetic activity was observed in these patients by Ruskin

Radiological features:

Radiologic features are similar for both types of atrophic rhinitis. Plain xrays show lateral bowing of nasal walls, thin or absent turbinates and hypoplastic maxillary sinuses.

CT scan findings:

1. Mucoperiosteal thickening of paranasal sinuses

2. Loss of definition of osteomeatal complex due to resorption of ethmoidal bulla and uncinate process

3. Hypoplastic maxillary sinuses

4. Enlargement of nasal cavity with erosion of the lateral nasal wall

5. Atrophy of inferior and middle turbinates

Coronal CT image of nose and sinuses showing classic changes of atrophic rhinitis

This is a coronal CT scan plain of Nose and paranasal sinuses.

It shows thinned nasal mucosal lining.

The turbinates appear to be atrophic.

The nasal cavities appear to be excessively roomy on both sides.

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Rhinolith

Introduction:

Rhinoliths are calcareous deposits (stone like) inside the nasal cavity. These stone like structures are highly friable and may crumble when crushed. Rhinoliths since they crumble easily can be removed after crushing with a luc's forceps via the nasal cavity [1]. Since the rhinolith in this patient was very large extending up to the choana it was removed via lateral rhinotomy approach in order to avoid excessive injury to nasal mucosa during the process of removal.

Rhinoliths are also known as nasal calculi are calcareous deposits present inside the nasal cavity .

Rhinoliths are of two types: Exogenous and Endogenous.

Exogenous rhinolith: If concretions occur around a impacted foreign body then it is considered to be exogenous in nature. These calcareous deposits around intranasal foreign bodies is the most common variety of rhinolith [2].

Endogenous rhinolith: If concretions occur around blood clot / inspissated foreign body then it is considered to be endogenous in nature.

This condition is commonly diagnosed by history and anterior rhinoscopy [3] . This condition is common in adults and elderly individuals. Unilateral foul smelling blood tinged nasal discharge in an adult should always raise suspicion of rhinolith. Since rhinoliths are commonly seen in the anterior nasal cavity, anterior rhinoscopic examination of nose clinches the diagnosis [4].

Patients with rhinolith usually present with:

1. Unilateral nasal obstruction

2. Unilateral foul smelling blood tinged nasal discharge

3. Hard mass inside the nasal cavity

Coronal CT of nose and sinuses showing radio opaque mass occupying the floor of right nasal cavity (Rhinolith)
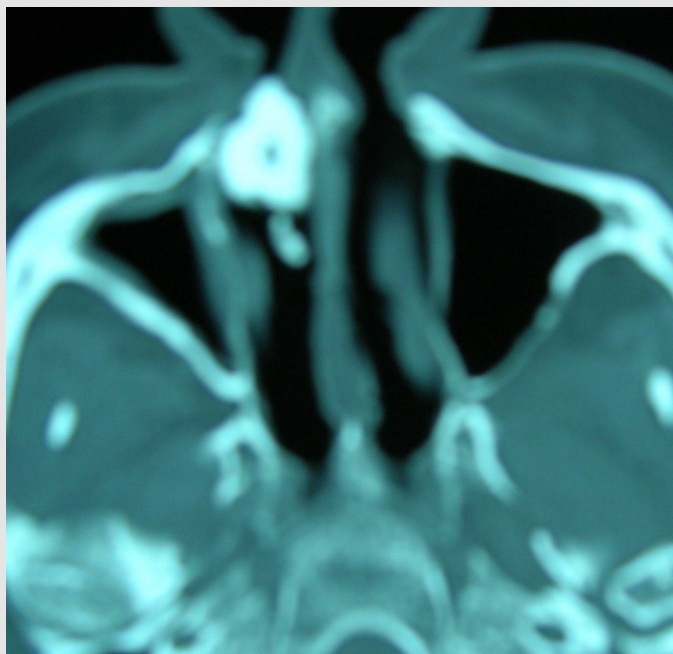
Axial CT of nose and sinuses showing rhinolith

The term rhinolith is derived from Greek (rhino – nose lithos – stone). It is considered to be a rather rare condition i.e. About 1 in 10,000 otolaryngology patients . It was Bertholin who first gave the accurate description of this condition in 1654 . Rhinoliths are usually irregular brownish / grey colored masses present in the anterior portion of the nasal cavity.

For some unknown reason males seem to be commonly affected than females . The exact pathogenesis involved in the development of rhinolith is still not known. It has been suggested that impacted foreign body / mucous plugs / blood clot may incite inflammatory reaction and stimulate deposition of minerals and salts. The salts which gets deposited around the nidus is derived from nasal secretions, tear and inflammatory exudate . The nidus of rhinolith is usually a foreign body [5].

Even gauze swabs inadvertently left inside the nasal cavity following surgery has been known to cause rhinolith. Radiology is usually diagnostic. Typical radiological picture is radio opacity with sometimes central opacity. The central radiolucency could be due to the presence of organic material which could have formed the nidus for rhinolith. This description was first given by Mac Intyre in 1900 [6]. CT scan usually cannot differentiate rhinolith from other calcified masses.

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Rhinoporidiosis

Introduction:

Rhinosporidiosis has been defined as a chronic granulomatous disease characterised by production of polyps and other manifestations of hyperplasia of nasal mucosa. The etiological agent is Rhinosporidium seeberi [1].

Rhinosporidium seeberi: was initially believed to be a sporozoan, but it is now considered to be a fungus and has been provisionally placed under the family Olipidiaceae, order chritridiales of phycomyetes by Ashworth [2]. More recent classification puts it under DRIP'S clade. Even after extensive studies there is no consensus on where Rhinosporidium must be placed in the Taxonomic classification. It has not been possible to demonstrate fungal proteins in Rhinosporidium even after performing sensitive tests like Polymerase chain reactions [3].

A separate chapter has been dedicated to this condition because it is uniquely common in south east Asian countries. Unless anterior cuts of CT scans of nose and sinuses are interpreted with care and caution this condition can invariably be missed radiologically.

Clinical features:

Patients usually present with bleeding from the nose. Lesions in the nose can be polypoidal, reddish and granular masses. They could be multiple pedunculated and friable. They are highly vascular and bleed easily. Their surface is studded with whitish dots (sporangia). They can be clearly seen with a hand lens. The whole mass is covered by mucoid secretion. The rhinosporidium in the nose is restricted to the nasal mucous membrane and does not cross the muco cutaneous barrier.
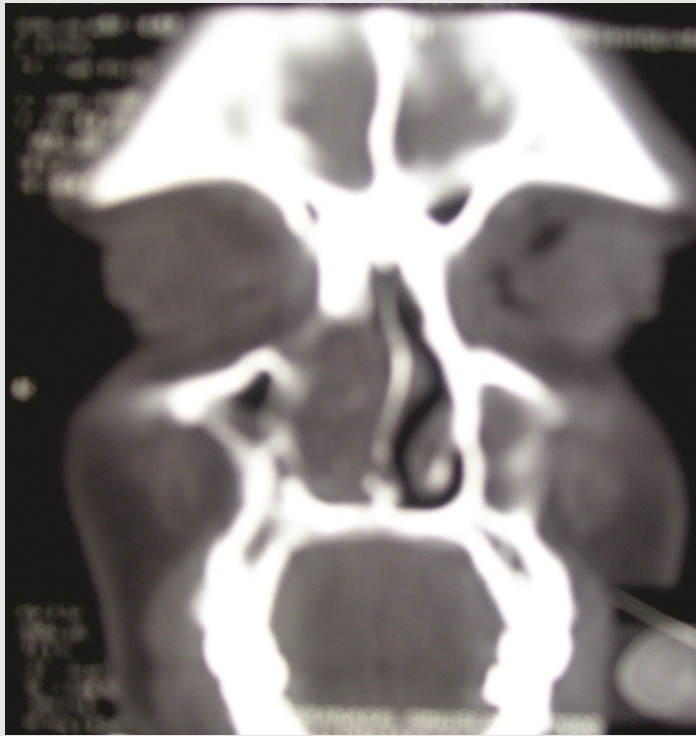
Coronal CT of nose and sinuses showing soft tissue mass involving the entire right nasal cavity. Note involvement of lacrimal sac also close to the medial canthal area
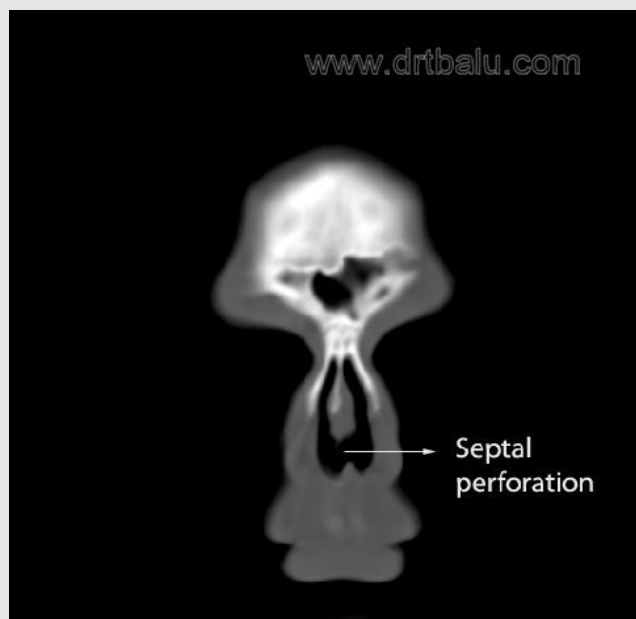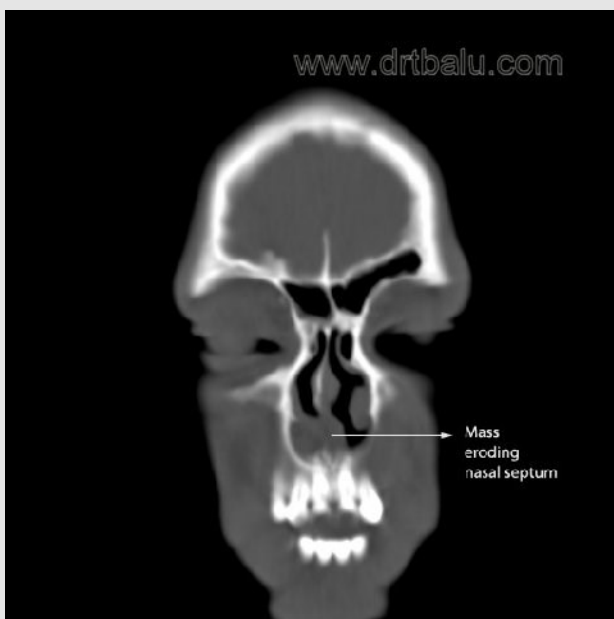
Coronal CT image of nose and sinuses showing soft tissue lesion in the right inferior meatus. Note the associated septal perforation in the next cut. So far this is the first case of septal perforation due to rhinosporidiosis reported so far

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Cystic lesions of Upper Jaw

Introduction:

International Classification of Diseases (ICD 10) classifies odontogenic cysts involving upper jaw into:

1. Radicular cysts

2. Dentigerous cysts

3. Primordial cyst

4. Lateral periodontal cyst

5. Residual cyst

6. Odontogenic keratocyst

7. Calcifying odontogenic cyst (Gorlin cyst)

8. Globulomaxillary cyst

These cysts are the most common cystic lesions involving maxillofacial area[1]. Cystic lesions are common in the jaw bones than anywhere else in the body because of the presence of epithelial cell rests which are commonly left behind following odontogenesis [2].

Radicular cysts:

Synonyms – Periapical cyst, dental cyst

This is the commonest of all odontogenic cysts [3]. These cysts could also be considered as an inflammatory cyst originating from Malassez's cell rests [4]. These cysts are caused by root infections involving roots of teeth closely related to maxillary sinus antrum. Infections / inflammation releases toxins at the apex of the tooth leading on to periapical inflammation. They stimulate the Malassez's cell rests which can be found in the periodontal ligament resulting in periapical granuloma which could either be infected or sterile. These cysts could well be sterile if the patient had received antibiotic therapy for dental infections. Radiological differentiation between granuloma and cyst could prove to be rather difficult.

The general rule of the thumb being if the lesion is large in radiological imaging then it should be considered as cyst. These cysts increase in size at the expense of the surrounding bony barrier. This expansion is caused by pressure effects and effects of inflammatory enzymes over the surrounding bone. These cysts are lined by stratified squamous epithelium without keratin formation. Evidence of inflammation can be seen along the cyst wall.
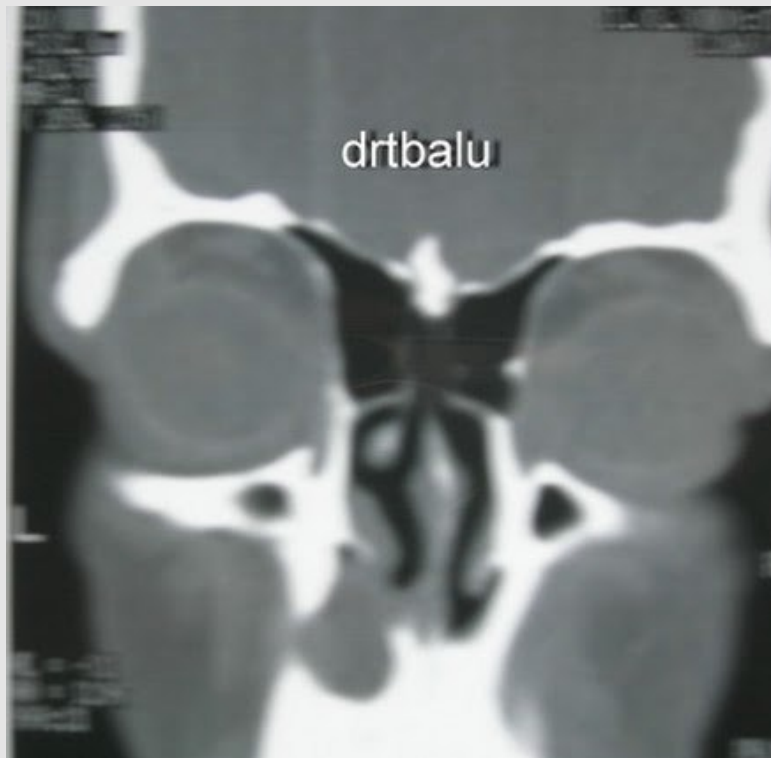
Coronal CT image of nose and sinuses showing radicular cyst of upper jaw

Pathophysiology of radicular cysts:

1. Inflammatory mediators / enzymes

2. Bacterial toxins

These two factors have been implicated as the probable factors contributing to Radicular cysts.

Among these two Bacterial toxins play a rather vital role. Bacterial endotoxins have been found in large amounts in and around necrotic tooth.

These toxins have been shown to be mitogenic [5]. These endotoxins also stimulate expression of cytokines and chemokines [6]. Inflammatory mediators and proinflammatory cytokines released by the host tissue are known to modulate the biochemical activity of epidermal growth factor (EGF) there by causing increased proliferation of cellular elements. They also stimulate local fibroblasts into hyperactivity by expressing Keratinocyte growth factor. The epithelial cell rests of Malassez are usually quiescent / stable cells. These cells are in the G0 phase [7] of their cell cycle. These cells need to be exposed to extracellular signals to push them into the cell cycle proper. These extracellular signals are collectively known as Mitogen.

Experimentally a cell can be identified to be in the proliferative phase by their ability to express markers like PCNA and Ki-67. Ki-67 marker is present in cells belonging to all phases of cell division except G0 phase. Studies reveal increased levels of PCNA and Ki-67 markers in the epithelial lining of radicular cysts [8.]

The actual binding of Mitogen (growth factor) to receptors present on the cell membrane surface initiates a series of intracellular reactions pushing the cell into mitotic phase.

Probable growth factors (Mitogen) involved in the pathogenesis of radicular cysts include:

1. EFG & KGF – released by stromal fibroblast

2. TGF-α – released by macrophages and lymphocytes

3. IGF (Insulin like growth factor) – released by stromal fibroblasts

In the pathophysiology of formation of radicular cysts mediators released by inflammatory cells (macrophages and lymphocyts) play a vital role [9].

Enlargement of radicular cyst:

This invariably occurs at a rather slow pace. Various factors influence the rate of expansion. These factors include:

1. Mural growth

2. Hydrostatic enlargement

3. Bone resorbing factor [10]

Rapid expansion of radicular cyst is associated with increase in hydrostatic pressure within the cyst. The hydrostatic pressure within the cyst is higher than that of capillary pressure, causing fluid to enter from the capillaries into the cyst cavity. This high hydrostatic pressure within the cyst has been attributed due to the amount of high molecular weight protein present in the cyst fluid. This protein is released by inflammatory cells in response to inflammatory stimulus.

Role played by mast cells in radicular cyst enlargement:

Mast cells play a significant role in radicular cyst enlargement [11]. Studies reveal that there are increased number of mast cells in the subepithelial zone of these cysts. Mast cells contribute to increase in the size of these cysts in the following manner:

1. By directly releasing heparin into the lumen

2. By releasing hydrolytic enzymes

3. By releasing histamine which causes transudation of serum proteins [11]
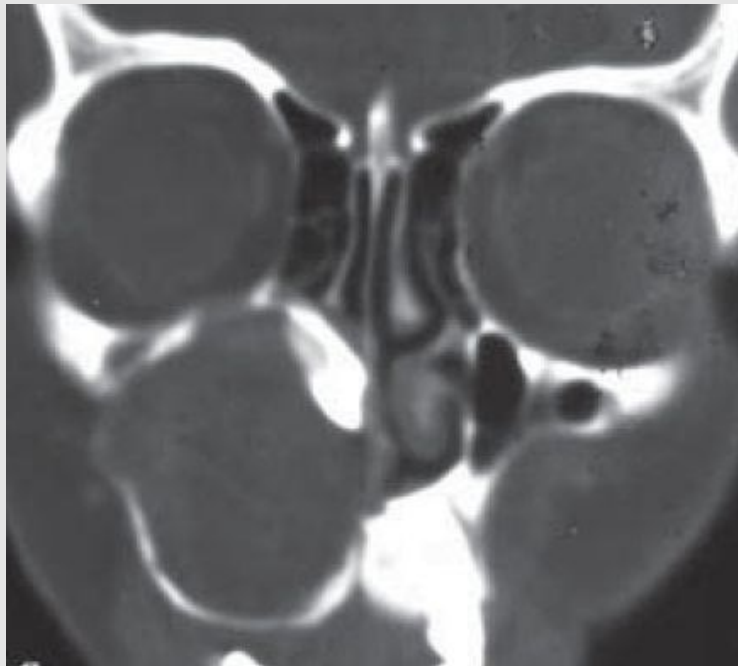
Coronal CT of nose and sinuses showing a large radicular cyst involving right side of upper jaw

Bone resorption by radicular cysts:

Radicular cysts causes resorption of alveolar process of maxilla. Osteoclasts have been known to cause this bone resorption. Osteoclasts need to be activated before it can reabsorb bone matrix.

Osteoclasts can be activated by:

RANKL

This reaction can be blocked by:

Osteoprotegerin (OPG)

RANKL is the molecule which activates osteoclasts by binding to its receptor RANK which is expressed on the surface of osteoclast precursor cells, where as OPG blocks this very reaction preventing activation of osteoclasts. Inflammatory mediators like cytokines and Interleukins stimulate proliferation of osteoclasts. In response to inflammation host cells are known to produce Matrix Metallo Proteinase (MMP).

This molecule is capable of degrading extracellular matrix like collagen, fibronectin and proteoglycans. Endotoxins released by bacteria also stimulates release of MMP. This substance helps osteoclasts in the bone resorption process.

Dentigerous cysts:

Also known as follicular cyst. This cyst is associated with unerupted tooth. This cyst is formed due to accumulation of fluid between the enamel epithelium and the completely formed tooth crown. This overlying cyst prevents teeth from erupting. This cyst is almost always associated with permanent dentition. In the upper jaw it is common in the canine tooth area. This cyst has its highest incidence during the 2nd and 3rd decades of life. Radiologically the presence of pericoronal radiolucency is a diagnostic pointer. This tumor should be differentiated from ameloblastoma, odontogenic keratocyst and calcifying odontogenic cyst. All these lesions manifest with pericoronal radiolucency in routine radiographs.

Coronal CT of nose and sinuses showing dentigerous cyst of upper jaw. Note un erupted teeth within the cyst cavity
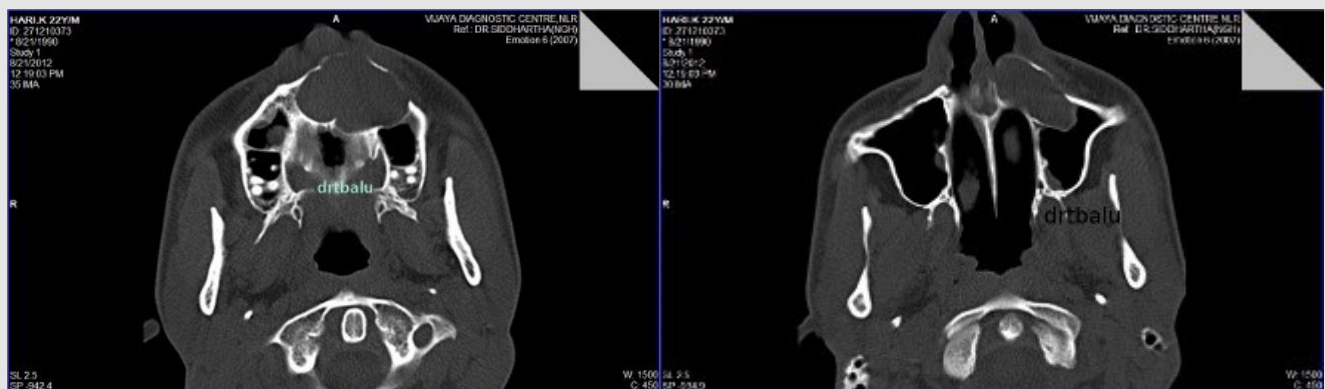
CT scan image showing cyst involving the anterolateral wall of left maxilla. Note the cyst extends up to the nasal cavity

Figure showing radio dense body within

The cyst cavity (? Un erupted tooth)

Primordial cyst:

This cyst arises due to cystic changes that occur in a developing tooth bud before the actual formation of enamel and dentin matrix. Since this cyst arises from developing tooth bud the tooth would be missing from the dental arch, or if teeth are all present then the presence of suprenumerary teeth should be suspected.

Lateral periodontal cyst:

This cyst develops from the periodontal ligament close to the lateral surface of erupted / unerupted teeth. This cyst is asymptomatic. The involved teeth is vital.

Residual cyst:

This cyst arises from remnants of epithelial cell rests left behind after extraction. This can also occur when a radicular cyst at the apex of the teeth is extracted. This cyst is commonly seen in the elderly.

Odontogenic Keratocyst:

This cyst has a keratinized epithelial lining. Major draw back of this condition is its propensity to recur even after complete removal. This cyst can mimic any of the cysts described above. It needs to be identified radiologically and pathologically. This cyst is seen between wide age groups.

Calcifying odontogenic cyst (Gorlin's cyst):

This is a very rare slow growing benign tumor like cyst. This condition manifests the features of solid mass while displaying features of tumor and cystic lesion. This cyst has equal incidence in both maxilla and mandible.

Globulomaxillary cyst:

This is actually a fissural cyst arising from epithelial inclusions trapped at the line of fusion between the globular portion of the median nasal process and the maxillary process. Pathologists consider this cyst to be odontogenic rather than developmental. Radiographs show these cysts as pear shaped / circular shaped between the roots of maxillary lateral incisor and canine. Both these teeth are vital in these patients.
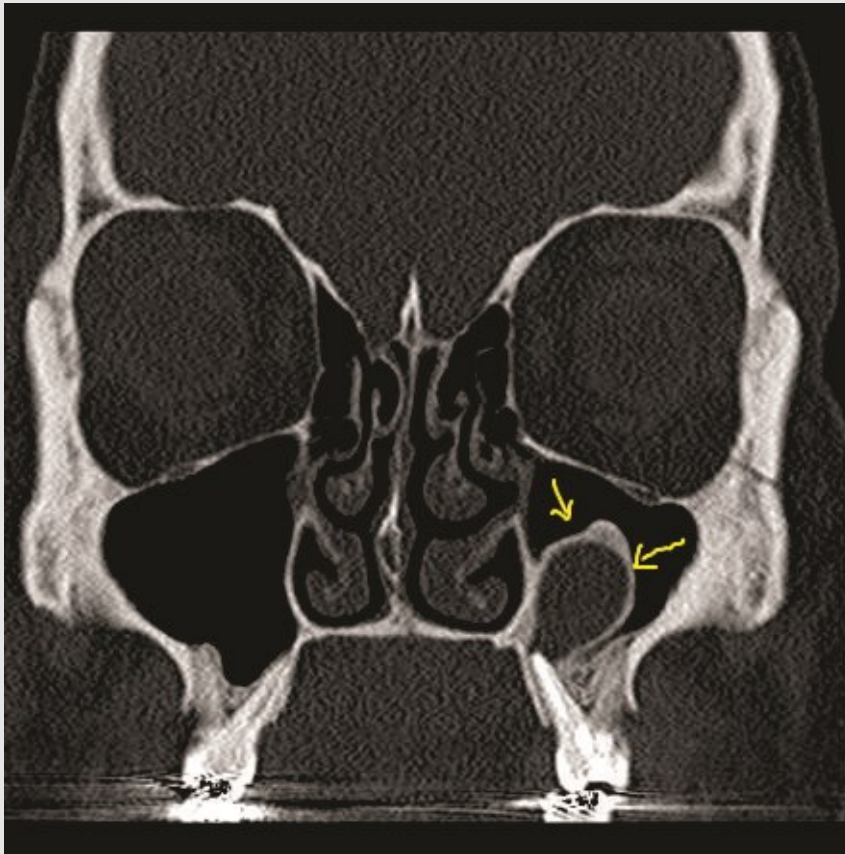
Coronal CT of nose and sinuses showing solitary translucent unilocular lesion with smooth corticated borders. When it occurs in maxilla then it could invade into the maxillary sinus as well
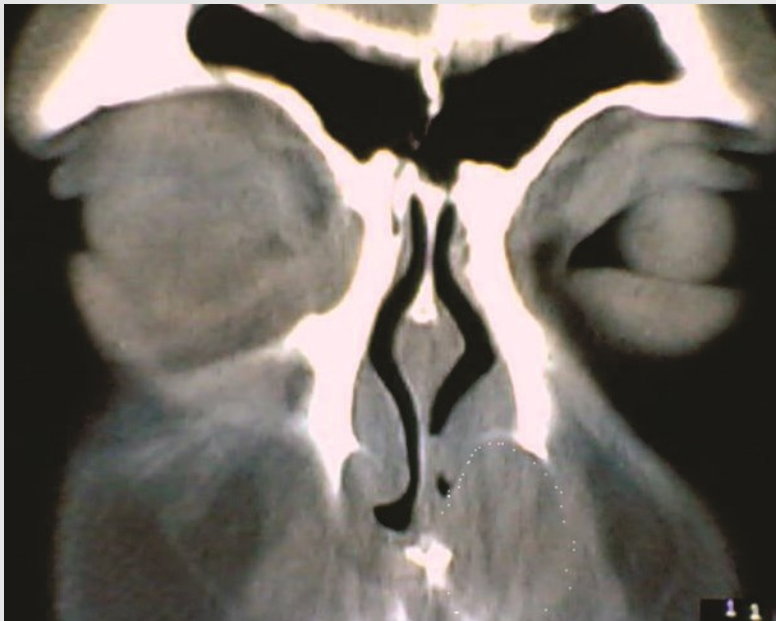
Coronal CT image of nose and sinuses anterior cut showing cystic lesion involving the upper alveolar margin extending into the nasal cavity. Naso labial cyst.

Un erupted tooth seen after removal of dentigerous cyst

Axial CT image showing globulo maxillary cyst. Note thin bony lining in some places

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Malignant tumors of paranasal sinuses

Introduction:

Malignant tumors of nose and paranasal sinuses constitute about 1% of all malignant tumors [1]. These tumors also constitute about 3% of head and neck malignancies. Malignant tumors of maxilla are more common in males in fact twice as common as in females. They are commonly diagnosed in patients in the age group of 50 – 70 years [2].

Histologically the commonest type of malignancy in this area is squamous cell carcinoma [3]. Other histological types like adenocarcinoma, sarcomas, neuroblastomas, lymphomas and malignant melanomas are rare [4]. These tumors are very difficult to treat because:

1. Of the complex adjacent anatomy (orbit, skull base etc)

2. These patients present fairly in the late stage of their disease

Among the sinus malignancies, maxillary sinus malignancy happens to be the commonest, followed by ethmoids and sphenoid sinuses.

Malignant tumors involving maxilla has poor prognosis because they present late [5].

Malignant lesions involving sinuses have a propensity to spread via areas of least resistance. This spread could involve adjacent vital areas like:

1.   Orbit

2.   Anterior skull base

3.   Pterygopalatine fossa

4.   Spread into middle cranial fossa

Areas of least resistance include:

1.   Medial wall of maxillary sinus

2.   Inferior wall of orbit because it is weakened by the presence of neuro-vascular bundle

3. Anterolateral wall of maxilla to involve skin. Skin involvement indicates that the tumor is fairly advanced because nodal involvement is common in these patients.

Roughly 70% of sinonasal malignancies occur in maxillary sinus [6]. 20% of malignant tumors occur within the nasal cavity while the remaining 10% is constituted by ethmoid and sphenoid sinus malignancies [7].

Role of CT scan in patients with sinus malignancies include:

1.   To assess the anatomical extent of the lesion

2.   To look for involvement of critical areas like skull base and orbit which could drastically change the prognosis
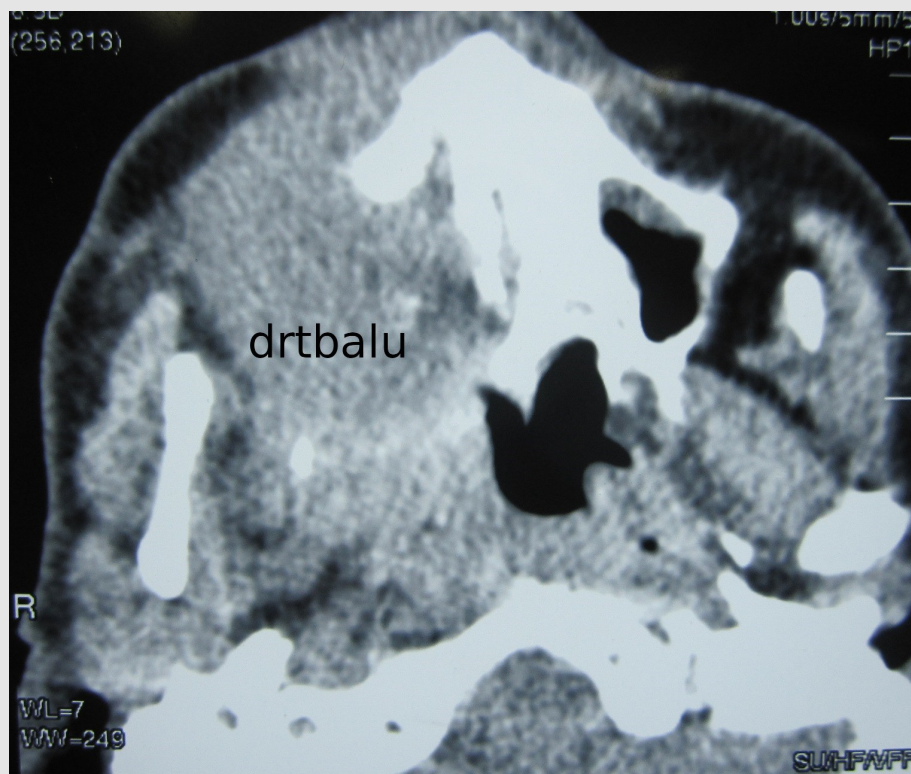
Axial CT image showing expansile lesion involving right maxillary sinus with erosion of anterolateral wall of maxilla. Note erosion of posterior wall of maxilla with extension into pterygopalatine fossa. Pterygoid plates cannot be visualized on the right side
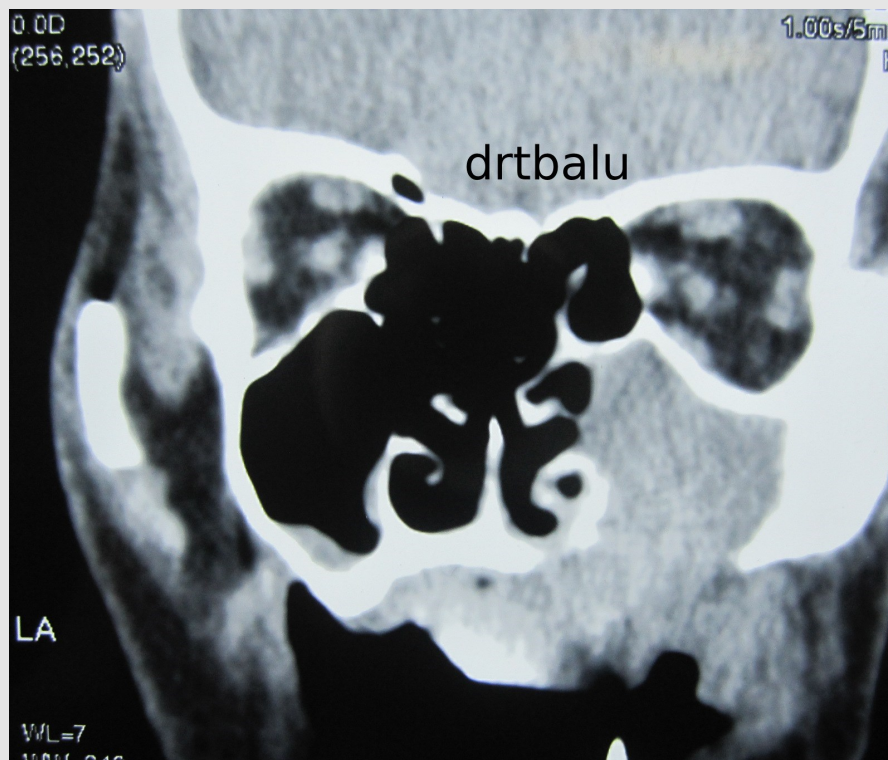
Coronal CT image of nose and sinuses showing mass lesion within left maxillary sinus with erosion of palate
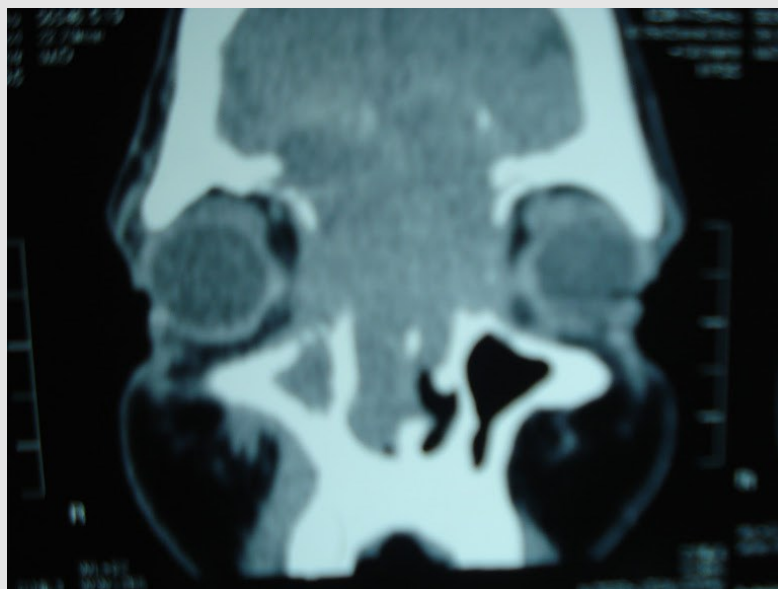
Coronal CT of nose and sinuses showing mass arising from right nasal cavity eroding nasal septum, involving the opposite side. Note erosion of anterior skull base. Right maxillary sinus haziness is due to reactive sinusitis. Dural breach by the tumor can be identified only in a contrast CT or MRI. Cartilaginous portion of nasal septum resists malignant erosion. In this picture the bony portion is eroded. Medial wall of right orbit has also been eroded
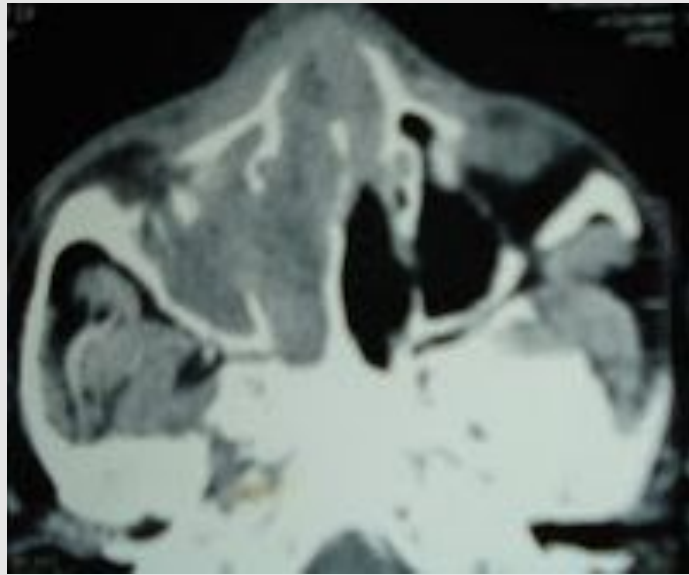
Image showing Axial CT of nose and sinuses showing malignant tumor arising from right maxilla eroding medial wall of maxilla to involve the nasal cavity. Note erosion of anterolateral wall of maxilla causing skin involvement

Coronal CT of nose and sinuses showing expansile, erosive lesion involving right maxillary sinus. Note medial wall of maxilla has been destroyed. Alveolar margin of right maxilla has been partially destroyed. In these patients loosening of teeth could be a predominant symptom which should not be ignored.

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